# JOURNAL

OF THE

# AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. XIX. FEBRUARY, 1907. No. 1.



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## U. S. S. *CALIFORNIA.*

### DESCRIPTION AND OFFICIAL TRIALS.


BY G. W. DANFORTH, LIEUTENANT, U. S. NAVY, MEMBER.


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The *California*, armored cruiser No. 6, belongs to a class of six vessels authorized by Congress in June, 1900. The other vessels of this class are the *Colorado*, *Pennsylvania*, *Maryland*, *West Virginia* and *South Dakota*. The contract for the *California* was signed by her builders, the Union Iron Works, San Francisco, on January 10, 1901, requiring her completion in thirty-six months, at a price of $3,800,000 exclusive of armor, ordnance, boats, portable furniture and lesser outfit usually furnished by the Government. The time for completion was extended in three stages to June 30, 1906, due to a prolonged labor strike, delays in reorganizing the labor forces after the strike, changes in plans and specifications, and other causes of less import; and a further extension is asked for in consequence of the earthquake and fire

which prostrated San Francisco in April, 1906. The most important change in the machinery was that necessary for outboard instead of inboard-turning propellers, this having been made before the engines were far advanced. The original contract provided for sheathing and coppering the hull, but this requirement was canceled. The hull was launched April 28, 1904, and the machinery was installed after launching. The dock trials of the engines took place from January 30 to February 8, 1906, and were entirely satisfactory.

The contract requires that an average speed of 22 knots per hour shall be maintained for four consecutive hours, with heavy penalties for failure to make this speed, but no premiums are allowed, as in former practice, for any excess of speed over 22 knots. The successful making of this speed insures preliminary acceptance only. Final acceptance is reserved until the vessel is tested in actual service, but this test must take place within six months after preliminary acceptance.

## HULL DATA.

The principal hull data are as follows:

| | |
|---|---|
| Length between perpendiculars, feet | 502 |
| on load water-line, feet | 502 |
| over all, feet and inches | 503–11 |
| Beam, extreme, feet and inches | 69–10½ |
| at load water-line, feet and inches | 69– 6½ |
| Molded depth, main deck, feet | 41 |
| bridge deck, feet and inches | 48– 6 |
| Normal mean draught, feet and inches | 24– 1 |
| Displacement at normal draught, tons | 13,680 |
| full load draught (full bunkers), tons | 15,138 |
| per inch of draught at load water-line, tons | 57.8 |
| Wetted surface, square feet | 43,350 |
| Coefficient of fineness, block, per cent | 57 |
| midship section, per cent | 95 |
| of load water-line, per cent | 69 |
| Cylindrical coefficient, longitudinal, per cent | 60 |
| Number of frames | 124 |
| water-tight compartments | 279 |

The bridge and main decks are laid with teak, the gun deck with linoleum, except in certain spaces like galley and toilet rooms, and the berth deck has no linoleum in the passages nor wash rooms.

The thickness and disposition of armor is the same as on vessels of this class, accounts of which are published in previous issues of this JOURNAL.

BATTERY.

| *No. of guns.* | *Caliber or kind.* | *Gun mark.* | *Remarks.* |
|---|---|---|---|
| 4 | 8-inch | V | Forty calibers long. |
| 14 | 6-inch | VIII | Fifty calibers long. |
| 18 | 3-inch | III | |
| 12 | 3-pdr. | IV | |
| 2 | 1-pdr. | V | |
| 2 | 3-inch field gun | I Mod. I | |
| 2 | Gatling | | |
| 2 | Colt | | |

There are fitted two stationary torpedo tubes under the protective deck, forward, to discharge below the water line.

MACHINERY.

The vessel has two main engines, each four-cylinder, triple-expansion, vertical, inverted, placed abreast in separate watertight compartments. These engines were designed for a horsepower of 23,000, when making about 120 revolutions per minute and with a steam pressure of 250 pounds at the high-pressure cylinder. The order of arrangement of cylinders, beginning forward, is F.L.P., H.P., I.P., A.L.P., and the cranks, at 90-degree intervals, are in the following sequence, H.P., I.P., F.L.P., A.L.P. The cylinders are supported by forged columns of mild steel, braced diagonally with 'thwartship and fore-and-aft bracing of the same material. Each engine crank shaft is forged in two pieces, each piece with cranks at 180 degrees, and the turning engine is attached by worm and tooth gearing to the flanges joining these shafts. The reversing shaft is located on the inboard side of each en-

gine, near the top of the framing. The Stephenson double-bar link valve gear is used.

Steam is supplied by sixteen water-tube boilers in eight watertight compartments, a center-line bulkhead separating the port and starboard pairs of boilers connected to a common smoke funnel. The eight boilers on each side of the ship have their steam spaces connected to a line of 8-inch piping which extends fore and aft over the boilers, throughout the fireroom spaces; the port and the starboard lines connecting in the forward firerooms, from whence branches carry steam to the dynamos and other auxiliaries located forward, and also connecting in the engine rooms, where branches supply adjacent auxiliaries. The main steam pipe, extending from the engines forward only over six boilers on each side, is not connected directly to the boilers, but is fed by the 8-inch line, which practically parallels it, through connections therewith controlled by stop valves. These connections are at three points on each side of the fireroom spaces, at one point on each side of the compartment between fire and engine rooms, and at the main separators. All this piping is of steel, seamless-drawn, with welded flanges.

MAIN ENGINE DATA.

| | H.P. *inches.* | I.P. *inches.* | L.P. *inches.* |
|---|---|---|---|
| Diameter of main cylinders | 38½ | 63½ | 74 |
| Stroke, all cylinders | 48 | 48 | 48 |
| Valves, one piston valve for each H.P. cylinder, diameter | 24½ | ... | ... |
| two piston valves for each I.P. cylinder, diameter | 27 | ... | ... |
| one double-ported flat valve for each L.P. cylinder, dimensions | ... | ... | 62½×80½ |
| travel | 10 | 10 | 10 |
| Balance valve pistons, diameter | 7 | 6 | 16 |
| Valve stems, diameter | 3½ | 3½ | 4 |
| through valves | 2½ | 2½ | 2 7/16 |
| at balance pistons | 1½ | 1½ | 1½ |
| Main steam pipe, diameter at throttle | 13 | ... | ... |
| Piston rods, diameter | 8½ | 8½ | 8½ |
| of axial holes | 4½ | 4½ | 4½ |
| length | 118 | 118 | 118 |

| | H.P. *inches.* | I.P. *inches.* | L.P. *inches.* |
|---|---|---|---|
| Cylinder walls, thickness | 2½ | 2 | 1¾ |
| liners, thickness | 1¾ | 1¾ | 1½ |
| diameter of studs in head | 1¾ | 1¾ | 1¾ |
| pitch of studs in head | 4 | 5½ | 6 |
| Port areas, minimum | 195 | 438 | 495 |
| Connecting rods, length center to center, feet | | | 8 |
| diameter, upper end, inches | | | 8½ |
| lower end, inches | | | 9½ |
| axial hole, inches | | | 5 |
| crosshead bolts (4), inches, outside, | | | 3½ |
| axial hole, inches... | | | 1¾ |
| crankpin bolts (2), inches, outside.. | | | 4¾ |
| axial hole, inches.. | | | 2 |
| Main bearings, length, five of 22; one (between I.P. and A.L.P.) inches | | | 35 |
| Main bearing bolts (four), diameter, inches | | | 3 |
| Crosshead, surface, ahead, square feet | | | 5.625 |
| backing, square feet | | | 2.64 |
| pins, diameter, inches | | | 11 |
| length, each, inches | | | 11 |
| Speed of pistons, in feet per minute, at 120 revolutions | | | 960 |
| Weight of pistons, complete, each, H.P., pounds | | | 1,933 |
| I.P., pounds | | | 3,009 |
| L.P., pounds | | | 3,489 |
| piston rods, each, pounds | | | 2,411 |
| crossheads, each, pounds | | | 2,338 |
| connecting rods, each, pounds | | | 7,165 |
| Crank shaft, diameter, inches | | | 19½ |
| of axial holes, inches | | | 10 |
| coupling disks, inches | | | 32 |
| thickness coupling disks, inches | | | 4½ |
| coupling bolts (10 in one flange), diam., inches | | | 3½ |
| pin, diameter, inches | | | 20 |
| length, inches | | | 23 |
| diameter axial hole, inches | | | 12 |
| webs, width, inches | | | 21 |
| thickness, inches | | | 12 |
| Thrust shaft, diameter at bottom of collars, inches | | | 17¾ |
| axial hole, inches | | | 10½ |
| length, feet | | | 17½ |
| collars, number on each shaft | | | 13 |
| diameter, inches | | | 27 |
| thickness, inches | | | 2½ |
| distance between, inches | | | 5 |
| total thrust surface each shaft, sq. feet | | | 29.35 |
| actual bearing surface of horse shoes, each shaft, square feet | | | 14.26 |

| | |
|---|---|
| Thrust-bearing side rods (two to each bearing), diameter, each, inches | 4¼ |
| Line shaft, diameter, inches | 17¼ |
| axial hole, diameter, inches | 10¼ |
| coupling discs, diameter, inches | 33¼ |
| coupling bolts (ten in each flange), diameter, inches | 3¼ |
| length (one length each engine), inches | 241 |
| number of bearings to each length | 1 |
| length of bearing, inches | 27 |
| weight of shaft, pounds | 11,900 |
| Stern-tube shaft, diameter, without casing, inches | 18¼ |
| axial hole (at after end, 7 inches), inches | 10¼ |
| length (one to each engine), inches | 490¼ |
| weight, pounds | 25,600 |
| steel coupling sleeve, diameter, inches | 26 |
| cotters (one in each end of sleeve) thickness, inches | 3¼ |
| width at ends, inches | 9 and 10¼ |
| Propeller shaft, diameter, inches | 18¼ |
| axial hole, diameter, forward end, inches | 7 |
| along shaft, inches | 10¼ |
| after end, inches | 9 |
| length (one to each engine), inches | 570¼ |
| Reversing engine, diameter, steam cylinder, inches | 16 |
| controlling cylinder, inches | 9 |
| stroke, inches | 22 |
| Turning engine, two steam cylinders, diameter, each, inches | 7 |
| stroke, inches | 6 |

| Clearances, main engines, expressed in per cent. of stroke: | *Top.* | *Bottom.* |
|---|---|---|
| Starboard high-pressure | 24.91 | 22.57 |
| Port high-pressure | 25.34 | 23.16 |
| Starboard intermediate-pressure | 22.25 | 20.24 |
| Port intermediate-pressure | 22.33 | 20.49 |
| Starboard forward low-pressure | 13.19 | 12.68 |
| Port forward low-pressure | 13.65 | 12.29 |
| Starboard after low-pressure | 13.15 | 12.53 |
| Port after low-pressure | 13.08 | 12.52 |

VALVES AND VALVE SETTINGS.

| | H.P. cylinder. | | I.P. cylinder. | | F.L.P. and A.L.P. cylinders, each. | |
|---|---|---|---|---|---|---|
| Number of valves, one engine | 1 | | 2 | | 1 | |
| Type | Piston | | Piston | | Double-p't'd slide | |
| Diameter of valves, inches | 24½ | | 27 | | ... | |
| Travel of valves, inches | 10 | | 10 | | 10 | |
| Side of valve on which steam is taken | Inside | | Outside | | Outside | |
| Angular advance, degrees and minutes | 25–10 | | 38–45 | | 45–30 | |
| Width of port, and length of slide valve, inches | 4½ | | 4½ | | 4×67½, double | |
| | *Top* | *Bottom* | *Top* | *Bottom* | *Top* | *Bottom.* |
| Steam opening, linear inches | 3½ | 3 7/16 | 2 11/16 | 2½ | 2 of 2 1/16 | 2 of 2 1/16 |
| area of sq. in. | 237.86 | 260.96 | 407.80 | 435.20 | 304.84 | 335.34 |
| Exhaust opening, inches | 3 13/16 | 3 11/16 | full pt. | 4 | full port | 3⅞ |
| area sq. in. | 265.04 | 250.09 | 682.38 | 606.56 | 552 | 517.5 |
| Steam lap, inches | 1½ | 1 1/16 | 2 5/16 | 2½ | 2⅝ | 2 5/16 |
| Exhaust lap, inches | 1 5/16 | 1 1/16 | ¼ | 1 | ¼ | 1½ |
| Steam lead, linear inches | 1/16 | 1/32 | 1/16 | 3/32 | 1/16 | 1/16 |
| Cut-off, in decimal of stroke, maximum, per cent | 89.06 | 86.18 | 76.3 | 65.1 | 66.5 | 55 |
| Exhaust release, inches from beginning of stroke | 47½ | 47½ | 37½ | 44½ | 42½ | 40⅝ |
| Compression, inches from end of stroke | 6⅝ | 4½ | 9½ | 6⅝ | 8½ | 6⅝ |
| Steam admission, inches before end of stroke | 9/16 | ⅛ | 1/16 | 1/16 | 1/16 | ¼ |

MAIN ENGINE AUXILIARIES.

There is a condenser for each main engine, located outboard of the engine, cylindrical, with steel shell 7 feet 5 inches in diameter, and composition heads. There are 6,280 seamless-drawn Muntz-metal tubes in each condenser, 14 feet 2 inches long, ⅝ inch outside diameter, and No.18 B.W.G. in thickness, tinned inside and outside. These give each condenser a cool ing surface of 14,391 square feet. Each condenser is supplied with cooling water by a centrifugal pump, driven by a vertical cross-compound engine. The pump has double inlets, a vane 48 inches in diameter, and the suction and discharge openings are 21 inches in diameter, with a suction connection to the main drain 15 inches in diameter. The engine has a stroke of 12 inches, the high-pressure cylinder is 9 inches, and the low, 12 inches in diameter. At a speed of 180 revolutions per minute on the standardization trial each circulating engine developed 65 I.H.P. These pumps were built by the Union

Iron Works, all other principal pumps of the vessel having been built by other builders on the Pacific coast.

To each main condenser is attached an independent air pump of the usual design supplied to vessels to the U. S. Navy. The steam cylinders are 14 inches, and the air cylinders 35 inches in diameter, with a common stroke of 18 inches. Each of these pumps developed 13 I.H.P. at 20 revolutions per minute on the vessel's standardization run.

### BOILERS.

Steam for all uses of the vessel is supplied by sixteen Babcock & Wilcox water-tube marine boilers placed in eight watertight compartments. These boilers are placed with fronts facing athwartship firerooms, the two boilers of each compartment having a common firing space 12 feet wide. Each fire room is connected directly with adjacent bunker, outboard by a watertight door, and each adjacent pair of port and starboard firerooms is connected by a similar door, through the middle-line bulkhead, which extends throughout the engine and boiler spaces. Fireroom passageways are convenient, and spaces around and above the boilers roomy.

All pressure parts of these boilers are of open-hearth steel plate and cold-drawn seamless steel tubes. All tubes are two or four inches in diameter, and tube ends are expanded into headers. The longitudinal seam of each steam drum is butted, and strapped inside and outside. There are four rows of rivets through both straps and two rows additional through the shell and inside strap.

The boiler casings are airtight, and consist of fire brick, ½-inch asbestos millboard, and 2 inches of magnesia block backed with galvanized steel plates about $\frac{1}{16}$-inch in thicknes braced with angle irons and bolted to the boiler foundations. Openings are provided in casings for cleaning. The fire fronts and fire and ash doors are of wrought-steel plate. All pressure parts were tested to an internal hydrostatic pressure of 500 pounds per square inch at the works of the builders. The principal boiler data are as follows:

| | |
|---|---|
| Working pressure, per gauge, pounds per square inch | 265 |
| Heating surface, all boilers, square feet | 70,928 |
| Grate surface, all boilers, square feet | 1,591.36 |
| Length of grates, feet | 7 |
| Ratio of heating to grate surface | 44.57 |
| Diameter of opening of safety valves (three each boiler), inches, | 4 |
| Thickness of 2-inch generating tubes, B.W.G. | 8 |
| 4-inch generating tubes, B.W.G. | 6 |
| Outside diameter of drum, inches | 42 |
| Thickness of drum plate, inches | 1½ |
| Tensile strength of drum plate, pounds per square inch | 60,000 |
| Thickness of convex drum heads, inch | ¾ |
| Number of boilers per smoke stack | 4 |
| Height of smoke stack above grate bars, feet | 93 |
| Area through smoke stack, square feet | 58.99 |
| Ratio grate surface to stack area | 6.7 |
| Weight of boiler dry, ready for service, pounds | 95,891 |
| water, one boiler, at steaming level and temperature (410 degrees), pounds | 15,214 |

BOILER FEED SYSTEM.

For use in feeding the boilers there are four main feed pumps, exclusively for this use, and eight auxiliary feed pumps connected also for fire and bilge service and for pumping out boilers.

The main feed pumps are simple, double-acting, vertical, with central-packed plungers. Dimensions are, steam cylinders, 14 inches diameter; water cylinders, 10 inches diameter; stroke, 18 inches. Two of these pumps are placed on the forward bulkhead of each engine room, all draw water only from the pipe connecting the two main feed tanks, and each pair delivers water primarily to the boilers on one side of the ship, but a cross connection of the feed mains in the forward fire-rooms enables any of these pumps to supply any boiler.

The auxiliary feed pumps, one in each boiler compartment, are of the same type as the main feed pumps, with 12-inch steam cylinders, 8-inch water cylinders and 12-inch stroke. Each auxiliary pump is connected to feed any boiler on its own side of the ship.

A feed-water tank is built outboard in each engine room, and these tanks, each having a capacity of 6,500 gallons,

receive the discharge from all main and auxiliary air pumps, traps and drains of steam lines. The tanks are arranged for using filtering material, and each has a pipe to conduct vapor to the atmosphere. To each tank is attached a hot-well pump for handling feed water. Each of these pumps has suction connection on its own side of the ship with the main air-pump suction pipe, the feed-water tank, the reserve feed-water tanks and the ship's side above the water line, for receiving fresh water from outside sources. The dimensions of these pumps are 12×16×18 inches.

The reserve feed-water tanks occupy three double-bottom compartments on each side of the keel, under the after fire-rooms, and their capacity is about 150 tons of fresh water.

The main feed pumps in each engine room discharge through a feed-water heater which heats with steam from the auxiliary exhaust. This discharge passes also through an oil separator in each engine room. There are by-passes to these heaters and separators.

## PROPELLERS.

The two propellers, outboard turning, each with three adjustable blades, are made of manganese-bronze, from Union Iron Works design. Each is a true screw, and the blades were carefully surfaced, balanced and measured for pitch by an especially-constructed machine, before leaving the shops. Hubs and blades are tinned. Each hub is fitted to the tapered end of its shaft, and is held in place by a steel key with rounded ends, fastened along the tapered part of the shaft, also by a nut on the end of the shaft, threaded opposite to the direction of ahead rotation of the propeller. This nut is itself secured against unscrewing by a special locking device. The principal data of the propellers are as follows:

| | |
|---|---|
| Diameter of propeller, feet | 18 |
| hub, feet | 5 |
| Disc area, square feet | 254.4 |
| Helicoidal area, square feet | 95 |
| Ratio mean pitch to diameter | 1.1944 |

Pitch is adjustable between 20 and 23 feet.
Distance of hub center above lowest point of keel, feet and inches, 10-00½
Weight, complete, starboard propeller, pounds..... 34,499
port propeller, pounds..... 34,820

OTHER STEAM AUXILIARIES AND EQUIPMENT.

In addition to the auxiliaries previously named, the ship is provided with others, as below noted:

The steering engine is of the usual type fitted on U. S. naval vessels, and was built by the Union Iron Works.

The boilers are fitted with the Howden system of forced draft. Air is supplied by a blower over each boiler, with a fan 69 inches in diameter, driven by a compound engine of 6-inch stroke and with cylinders 5 and 8 inches in diameter, respectively.

In each engine room is located an auxiliary condenser, with air and circulating pumps, receiving exhaust steam from auxiliary engines only. A condensing unit is also installed in the lower dynamo room for exclusive use of the seven dynamo engines.

For fire and bilge service there is, beside the eight auxiliary feed pumps, a pump in each engine room, 12×10×12 inches, simple, vertical, double-acting. A crank-pit pump is attached at the forward end of each main engine to the crank-shaft end.

An ash-hoisting engine of usual type is fitted in the drum room over each boiler compartment. These engines are supplied with steam at reduced pressure.

A windlass engine is installed on the berth deck, forward. It is a simple, two-cylinder, vertical engine such as is commonly fitted on board U. S. naval vessels.

The evaporating plant consists of four horizontal evaporators of the type common to U. S. naval vessels, six distillers and necessary pumps. The evaporators have a combined capacity of 23,000 gallons and the distillers a combined capacity of 20,000 gallons in 24 hours. The pumps of this plant are an evaporator feed pump, 5½×5½×8 inches; an auxiliary-feed pump 4½×4×6 inches; a fresh-water pump 5½×5½×8

inches; and a distiller-circulating pump, also used as a sanitary pump, 12×16×18 inches.

An ice machine of the dense-air type is installed on the berth deck, forward, adjacent to the cold-storage rooms. Its capacity is three tons of ice per day, and it is connected for cooling the drinking water in the scuttlebutt, and the air in the magazines, in addition to its connections with the freezing tanks and the cold-storage rooms.

A steam-heating system, divided into circuits according to the needs of convenient heating, and controlled from the engine rooms, such as is usually fitted to vessels of the U. S. Navy, is installed.

The ship has a well-fitted machine shop capable of high-grade and varied work.

### ELECTRIC PLANT.

This vessel and class are fitted with unusually large and well-equipped electric plants. The *California*, as have other vessels of the same class, has two dynamo rooms, under the protective deck, one above the other, immediately forward of and extending across the same width as the firerooms. There are seven generating units, built by the Union Iron Works, and a condensing system for the exclusive use of the engines of these units. In the upper room are three 50-kw. units and the switchboard of the system, and the lower room contains three 100-kw. units, one 50-kw. unit, and the condensing outfit.

The engines are designed for an initial working pressure of 150 pounds per gauge, and are vertical, cross-compound. The 50-kw. engines have cylinders of 10 and 16½ inches diameter, respectively, with 10-inch stroke, and the 100-kw. engines have cylinders of 13½ and 23 inches diameter, respectively, with 12-inch stroke. The generators supply a voltage of 125 at the terminals. There are supplied two spare armatures for each size of generator. The wiring is of the two-wire feeder system.

The generators supply current for the following uses:

*a.* Four motor generators for gun elevating, generators 0 to 125 volts.

*b.* One dynamotor, Holtzer-Cabot Co., size ¼, for electric bells, which also have Leclanche cells, as a reserve battery.

*c.* One motor generator for telephones, same make and size as preceding. (Telephones work on 13 calling volts and 24 talking volts.)

*d.* Motors as below listed.

| *Quantity.* | *Aggregate H.P.* | *Use.* |
|---|---|---|
| 29 | 97.8 | Stationary ventilating equipment. |
| 6 | ... | Portable ventilating equipment. |
| 46 | 4.3 | Electric fans. |
| 30 | 30 | Operating watertight doors. |
| 34 | 85 | Chain-ammunition hoists. |
| 1 | 1 | Whip-ammunition hoist. |
| 4 | 44 | Turret-ammunition hoists. |
| 4 | 14 | Rammers, 8-inch guns. |
| 2 | 100 | Torpedo air compressor. |
| 4 | 60 | Turret turning. |
| 4 | 14 | Elevating 8-inch guns (supplied by motor generators "*a*"). |
| 8 | 200 | Boat cranes. |
| 7 | 210 | Deck winches. |
| 2 | 6 | Fresh-water pumps. |
| 1 | 1 | Dish washer. |
| 1 | 2.5 | Dough-mixing machine. |
| 1 | 7.5 | Laundry. |
| 2 | 10 | Engineer's workshop. |

*e.* Lighting fixtures, as below listed.

| *Quantity.* | *Use.* |
|---|---|
| 1 | Top light. |
| 1 | Masthead light. |
| 1 | Towing light. |
| 2 | Side lights. |
| 15 | Double brackets, living spaces. |
| 1 | Single bracket, living spaces. |
| 95 | Ceiling fixtures. |
| 126 | Battle lanterns. |
| 36 | Deck lanterns. |
| 33 | Magazine lanterns. |
| 11 | Signal lanterns. |

| *Quantity.* | *Use.* |
|---|---|
| 294 | Bulkhead lights. |
| 319 | Steamtight lights. |
| 69 | Bunker lights. |
| 152 | Watertight portables. |
| 6 | Non-watertight portables. |
| 72 | Desk lights. |
| 6 | Cargo reflectors. |
| 3 | Binnacle lights. |
| 6 | Engine-room telegraph lights. |
| 2 | Truck lights. |
| 6 | Parabolic reflector searchlights. |

The six searchlights require 450 ampères of current, and all other lights require a total of 625 ampères.

## STANDARDIZATION RUNS.

On October 4th, 1906, the *California* left San Francisco for Santa Barbara Channel to undergo official trial runs, having had a builder's trial in San Francisco Bay, mainly for adjusting compasses for a sea trip, a few days before departure. The vessel reached Santa Barbara October 5th in a dense fog, and fog prevented making the standardization runs until October 9th.

For the purpose of establishing the relation between the revolutions of the main engines and the speed of the vessel, to be employed soon afterward in determining the vessel's speed from the engines' revolutions, the usual standardization runs were made over a straight course marked out parallel to the shore, just west of Santa Barbara harbor. Fourteen runs were made over this course, one sea mile in length, at revolutions varying from 128.41 starboard engine and 129.27 port engine, to 102.27 starboard engine 101.32 port engine, per minute, the runs alternating in opposite directions over the course to show influence of tide. From this data two speed curves were established, and a mean curve then determined, eliminating tidal effect. This curve is shown on the accompanying diagram, Plate I.

The greatest speed made during these runs was at the rate of 22.756 knots per hour, on a run to the westward, immediately following a speed at the rate of 22.514 knots per hour on the preceding eastward run.

Before starting on these runs, the vessel's draught was observed as follows:

| | |
|---|---|
| Forward, feet and inches, . . . . . | 22– 8¼ |
| Aft, feet and inches, . . . . . | 24– 7 |
| Mean, feet and inches, . . . . . | 24– 1⅛ |
| Corresponding displacement, tons, . . . | 13,780 |

On completion of the runs, the following draughts were noted:

| | |
|---|---|
| Forward, feet and inches, . . . . . | 23– 7½ |
| Aft, feet and inches, . . . . . | 24– 3½ |
| Mean, feet and inches, . . . . . | 23–11½ |
| Corresponding displacement, tons, . . . | 13,663 |

The estimated mean draught at the middle of the high-speed runs was 24 feet 1 inch, with a corresponding displacement of 13,750 tons.

Throughout these runs the boilers supplied more steam than the engines could use, the safety valves blowing almost continuously. The ship vibrated very little, and no vibration was noticeable on the upper deck over the engine and fireroom spaces at any speed.

The higher speeds caused heating of all crank-pin brasses to varying degrees, though none gave serious trouble except the I.P. brasses, due to the relatively great power developed by these cylinders. The trial was not interrupted, although these brasses pounded considerably when their white metal ran out. The heating of these brasses was due primarily to the fact that the crank pins were oiled by pipes from the crossheads along the connecting rods and into the crank-pin brasses, conveying oil to the brasses by gravity alone. The steady and sufficient delivery of oil by these pipes was greatly interrupted by centrifugal force at high speeds, depriving the pins of the necessary lubrication.

Completing the standardization runs, the vessel anchored again in Santa Barbara harbor, and spent the following day in fitting new crank-pin brasses where needed, and in otherwise making ready for the continuous four-hour run at 22 knots per hour, as required by contract. It was determined from the speed curve that the main engines should run at an average of 122.85 revolutions per minute to develop 22 knots.

## FOUR-HOUR SPEED-TRIAL RUN.

On October 11th the speed run began in Santa Barbara Channel and continued about 2½ hours, when it had to be discontinued because of the lack of sufficient lubricant on the intermediate-pressure crank pins, causing them to heat excessively. On the following day the vessel returned to San Francisco, and, after refitting the crank-pin brasses where necessary, another attempt was made on October 22d to run the four-hour trial, this time at sea off San Francisco, though the same difficulty brought the run to an end after a continuance of about 2½ hours. A third attempt was made on October 26th, though this consisted only in getting the vessel up to full speed, when it was again demonstrated that the oiling pipes for the crank pins would not deliver oil satisfactorily at high engine speeds, although there was no difficulty with this lubrication when running at less than about 112 revolutions.

After this attempt, a centrifugal oiling arrangement was fitted to each main crank pin, which conveyed oil from a supplying receptacle to an annular grooved casting fastened to one web of each crank, concentric with the shaft. This casting was so fitted that centrifugal force impelled oil through a pipe from the casting into the hollow of the pin, and through the pin radially outward to the bearing surface. This simple apparatus solved the difficulty, and when, on November 12th, the vessel was taken to sea for another run, it was made successfully. No attempt was made to exceed the required engine speed, more than by a safe margin to insure the average required, as there was no premium for so doing; but the contract speed was made with ease, and it is apparent that after the engines have been in service sufficiently to work them to good bearing, this speed can be made with even greater ease.

On all these runs was used Harris Navigation (Cardiff) coal, screened and bagged.

There was installed in each fireroom an indicator to regulate the firing. This consisted essentially of a dial which flashed the numbers 1, 2, 3, 4, consecutively at any uniform

interval desired, at each flash ringing a small gong. All indicators were actuated electrically from a central source of power. In each fireroom the four furnace doors of the forward boiler were numbered alternately 1 and 3, and those of the after boiler were numbered alternately 2 and 4. The indicators were set to flash an identical number simultaneously in the four starboard firerooms, followed at the chosen firing interval by the same number simultaneously in the four port firerooms. In this way all the same numbered furnaces of the starboard boilers were fired at the same time, followed at the firing interval by all same numbered furnaces of the port boilers, this alternation between starboard and port continuing in cycles through the numbers in their regular order.

On the standardization runs the interval of firing was made twenty-four seconds between alternate starboard and port firings, but, as so frequent firing made much smoke and kept the safety valves lifted most of the time, the firing interval was lengthened finally to fifty-six seconds. Even at this interval on the successful four-hour run the boilers produced more steam than the engines needed to make contract speed, and very frequently a firing signal was passed without opening the furnaces in one or more firerooms, or at most opening only to level the fires, which were carried heavy at the back and light at the front, and were not sliced during the run. The boilers supplied steam so easily that the work of the firemen was light, and the air of the firerooms was very comfortable and not laden with dust. The smoke leaving the funnels was not heavy, even at its maximum.

The main engines, fitted with the centrifugal oiling gear for the crank pins, and all other machinery worked particularly well.

After this run the vessel's machinery was subjected to a thorough and careful inspection for defects developed by the tests imposed, but none were discovered. The only defect, that of the crank-pin oiling apparatus, had been entirely corrected by fitting centrifugal gear.

## PERFORMANCE.—FOUR-HOURS' OFFICIAL TRIAL.

NOVEMBER 12, 1906.

*Steam Pressures.* (*Average of one-half hourly observations.*)

| | *Starboard.* | *Port.* |
|---|---|---|
| Mean steam pressure at boilers, pounds gauge | 273.5 | |
| Mean steam pressure, H.P. steam chest gauge, pounds | 249.1 | 225.4 |
| 1st receiver (absolute), pounds | 149.5 | 146.2 |
| 2d receiver (absolute), pounds | 63.5 | 64.4 |
| Vacuum in condensers, inches of mercury, mean | 27.0 | 27.5 |

*Temperatures.* (*Average of one-half hourly observations.*)

| | | |
|---|---|---|
| Injection, degrees | 56.0 | 56.0 |
| Discharge, degrees | 119.0 | 100.0 |
| Hotwell, degrees | 122.0 | 122.0 |
| Feed water, degrees | 169.0 | 166.0 |
| Engine room, upper platform, degrees | 86.0 | 91.0 |
| working platform, degrees | 75.0 | 78.0 |
| Firerooms, above grating, degrees | 95.0 | |
| working level, degrees | 85.0 | |
| Smoke stacks, average, degrees | 620.0 | |

*Revolutions, or double strokes, per minute.* (*Average of one-half hourly observations.*)

| | | |
|---|---|---|
| Average revolutions, main engines, per minute | 124.17 | 124.99 |
| Mean revolutions, both engines, per minute | 124.58 | |
| Pumps, main air | 16.75 | 24.0 |
| circulating | 157.0 | 212.0 |
| feed, d.s., per minute | 25.6 | 22.8 |
| fire and bilge | 87.0 | 80.0 |
| Blower engines | 336.0 | 352.6 |
| Speed of ship, in knots per hour | 22.2 | |
| Slip of propeller, in per cent. of its own speed, based on mean pitch | 15.73 | 16.29 |
| Air pressure in firerooms, in inches of water, mean | 1.33 | |

*Mean Effective Pressures in Cylinders, in pounds per square inch.* (*Averages of cards taken at half-hourly periods.*)

| | | |
|---|---|---|
| Main engines, H.P. cylinder | 86.37 | 79.18 |
| I.P. cylinder | 46.68 | 51.31 |
| F.L.P. cylinder | 27.52 | 27.06 |
| A.L.P. cylinder | 26.88 | 27.24 |
| Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons | 55.63 | 56.53 |

## INDICATED HORSEPOWER.

| | *Starboard.* | *Port.* |
|---|---|---|
| Main engines, H.P. cylinder | 2,952.8 | 2,725.1 |
| I.P. cylinder | 4,410.9 | 4,879.9 |
| F.L.P. cylinder | 3,534.7 | 3,503.2 |
| A.L.P. cylinder | 3,420.0 | 3,526.3 |
| total | 14,308.4 | 14,634.5 |
| Collective H.P. of both main engines | **28,942.9** | |
| Air pumps, main | 10.1 | 15.8 |
| Circulating pumps, main | 50.0 | 82.6 |
| Feed pumps, main | 160.0 | 119.2 |
| Dynamo-condenser, air and circulating pumps | 4.0 | |
| Fire and bilge pumps | 8.0 | 2.7 |
| Forced-draft blowers | 145.2 | |
| Dynamo engines | 114.4 | |
| Total auxiliaries | **712.0** | |
| Collective I.H.P. main engines, air, circulating and feed pumps | **29,380.6** | |
| Collective, main and auxiliary engines in operation | **29,658.8** | |

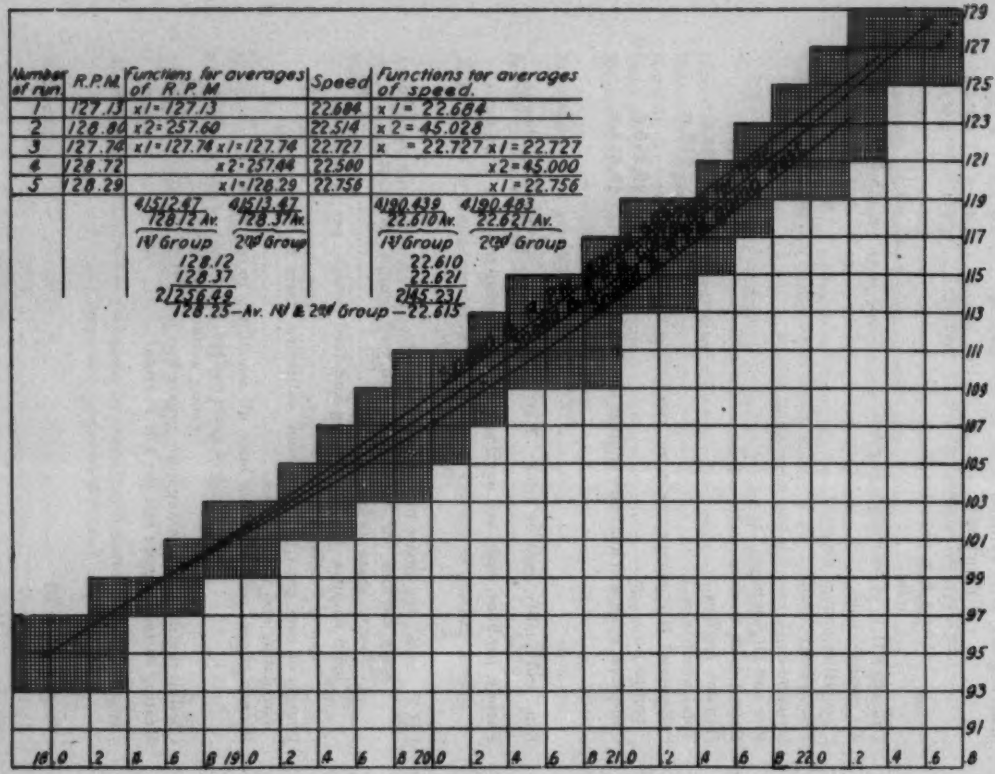
## COAL.

Kind and quality used on trial: Harris Navigation, screened and bagged.

Pounds, per hour, main and auxiliary engines, during trial..... 47,190.0

## DEDUCED DATA.

| | |
|---|---|
| I.H.P. (total) per square foot of grate surface | 18.63 |
| main engines, air, circulating and feed pumps, per square foot of grate surface | 18.46 |
| main engines, air, circulating and feed pumps, per square foot of heating surface | 0.414 |
| Pounds of coal per I.H.P. per hour, collective, main engines, air, circulating and feed pumps | 1.6 |
| Pounds of coal per I.H.P. per hour, all machinery in operation | 1.591 |
| square foot of grate surface, per hour | 29.65 |
| heating surface, per hour | 0.665 |
| Cooling surface (main condenser), square feet per I.H.P. (total) | 0.9698 |
| Heating surface, square feet per I.H.P. (total) | 2.39 |




"CALIFORNIA."—**Plate I.**

# U. S. S. *SOUTH DAKOTA.*

## DESCRIPTION OF OFFICIAL TRIALS.

By J. J. Raby, Lieutenant, U. S. Navy, Member.

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The *South Dakota* (Armored Cruiser No. 9), built by the Union Iron Works, San Francisco, California, is one of a class of six vessels authorized by Act of Congress dated June 7, 1900. She was the last of the class to have her official trials. Her sister ships are the *Colorado*, the *Pennsylvania*, the *West Virginia*, the *Maryland* and the *California*.

The contract for the *South Dakota* was signed by her builders on January 10, 1901, and she was to be completed in thirty-six months. Owing to labor troubles and the San Francisco fire the date of completion was extended in several stages to January 31, 1907, and the contractors have recently asked for a further extension to June 30, 1907. The contract price of the ship was $3,750,000, of which sum $1,500,000 was allotted to building and installing all machinery under the cognizance of the Bureau of Steam Engineering.

The keel was laid September 30, 1902, and the ship was launched July 21, 1904. Successful dock trials took place from March 20 to 27, 1906.

The *South Dakota* is practically a duplicate of the *California*, which vessel also was built by the Union Iron Works; and, as a description of the latter vessel by Lieutenant Danforth appears in this number of the Journal, it is quite unnecessary to describe the *South Dakota* here, except to give the valve data for the main engines, which data will be found in Table I, and to give the power curves and the indicator cards for the auxiliary machinery, shown on Plate I to V.

Profiting by the experience of several unsuccessful trials of the *California* the contractors, before taking the *South Dakota*

"California."—Plate I.

out, fitted centrifugal oiling gear for the crank pins of the main engines. They also rebabbitted the crank-pin brasses. The original babbitt in these brasses was the regular navy composition, and the babbitt was laid in blocks in the brasses, as may be seen from the sketch on Plate VI. The extensive oil grooves took up much of what should have been bearing surface. The brasses as rebabbitted had oil grooves cut as per sketch on Plate VI, and the increase of bearing surface over that of the original brasses amounted to about 300 square inches for each complete brass. The metal used for rebabbitting is a special "Bearing Metal for Armature Liners" manufactured in San Francisco, and it is somewhat harder than the metal called for by the Bureau specifications. It may have been necessary to rebabbitt the brasses in order to get more bearing surface for the crank pins, but it is not believed that the metal substituted is superior to the regular navy composition, for it did not take on so good a polish, the metal appeared dull in color, and seemed to flake in places. The original brasses might have stood the test with the new oiling gear fitted, but the builders, in order to make certain of a successful trial, were taking no chances.

On December 18, 1906, the *South Dakota* left the works for her builders' trial, which took place in San Francisco Bay. After the compass was adjusted, the ship steamed around Angel Island for several hours, and the maximum speed during the run was 110 revolutions. With a few minor exceptions, the main engines, the boilers and the auxiliary machinery functioned satisfactorily. The next day the ship proceeded to Santa Barbara and anchored off that place during the forenoon of December 20th. On the run down the coast the engines were speeded up to 120 revolutions for a short time and everything worked smoothly.

## STANDARDIZATION TRIAL.

On the morning of December 21st the *South Dakota* got under way shortly after 7·00, and at 8·14 began her standardization trial runs on the Goleta Point measured-mile course

situated about six miles west of Santa Barbara. The weather was fine and the sea smooth. Fourteen runs were made, seven to the westward and seven to the eastward, in order to eliminate influence of tide, and the first five runs were at maximum speed. The greatest horsepower developed on any run was 28,157.1 for main engines and 28,766.8 for all machinery, and the least was 9,262.5 for main engines and 9,507 for all machinery. The maximum number of revolutions per minute for a run was 125.58 starboard and 124.85 port, and the minimum 92.46 starboard and 91.87 port. The highest speed obtained on any one run was at the rate of 22.785 knots per hour. The H.P. and I.P. were set at maximum cut-off and the L.P. at minimum cut-off. The mean draught on trial was 24 feet 1 inch and the corresponding displacement 13,750 tons. The last run was completed at 11·20, after which the ship returned to her anchorage off Santa Barbara.

The standardization trial developed no serious defects. Engines, boilers and auxiliary machinery worked nicely, and though two valve guides ran hot and some of the crossheads and crank pins knocked slightly, there was no heating of bearings. Water was used freely on the bearings and about 380 gallons of lubricating oil was expended during the trial. So successful was the trial that the contractors' engineer did not deem it necessary to make any adjustments or inspect any bearing of the engines before the endurance run.

From the data obtained on the standardization runs a speed curve was constructed, which showed that the number of revolutions necessary to make the contract speed (22 knots) was 123.07. Plate VII shows the speed curve. On this plate is also shown the revolution-horsepower curve.

## FOUR-HOUR FULL-POWER TRIAL.

On the morning of December 22, 1906, the *South Dakota* got under way and stood down the Santa Barbara Channel to the eastward for her four-hours' official trial. The weather was fine with light southerly airs and smooth sea. The trial began at 7·55 with the ship steering an easterly course. Dur-

ing the latter half of the run the course was changed to the westward up the Santa Barbara Channel. The trial was finished at 11·55. The mean draught for the trial was 24 feet 1 inch and the corresponding displacement 13,750 tons. The average revolutions per minute for the trial were 125.23, and the corresponding speed from the speed curve gives an average speed of 22.24 knots per hour for the four-hours' run. The cut-offs were set as for the standardization runs, H.P. and I.P. maximum, L.P. minimum. The main engines developed 28,158.96 I.H.P., and the total I.H.P. for all machinery was 28,842.81. The coal used was Harris navigation, good quality, hand picked and sacked.

The engines, boilers and auxiliary machinery worked exceedingly well during the trial. There were rather heavy knocks in S.A.L.P. crank pin and P.A.L.P. crosshead and crank pin, and slight knocks in I.P. and H.P. crank pins, but otherwise everything ran beautifully about the main engines, and an examination after the run showed that all bearings were cool. About 100 gallons oil per hour was used for lubrication during the trial, and water was used freely on the main bearings. The boilers steamed easily, and careful supervision of the firing, water tending, and running of forced-draft blowers kept the safety valves from lifting very much and the boilers from priming at all. The auxiliary machinery gave no trouble.

An electric time-firing device was used to give the signals for firing. The time was divided into eight firing intervals, and the average firing interval during the trial was about 56 seconds. The furnace doors on the forward boiler of each fireroom were numbered alternately 1 and 3, while the doors on the after boiler were numbered 2 and 4. The electrical connections in the time-firing device were so arranged that the signals for firing were made as follows: 1S, 1P, 2S, 2P, 3S, 3P, 4S, 4P. Each boiler was therefore fired about every 112 seconds on the average.

This same time-firing device was used for the signal to feed the boilers, and, except when necessary, each boiler was fed only during the time for firing that boiler. In this way the

work of the feed pumps was made uniform, the distribution of feed water was well regulated, and the water was kept at the proper level in the gauge glass. I believe this to be a very good way of feeding the boilers during full-power trials when the feed pumps are running at their greatest capacity, though when steaming at moderate speeds and the feed pumps are not hard worked the continuous feeding of the boilers might be more satisfactory.

The boilers steamed so easily to supply sufficient steam for the engines that the firing interval was rather long, and the average air pressure in the ash pans was only 1.35 inches, though 2 inches was allowed by the machinery specifications. The firemen seemed to be spending most of the time leaning on the handles of their shovels. The smoke pipes emitted little smoke and the average temperature of the smoke-pipe gases was 582 degrees at a point about 33 feet above the grates. The coal consumption was unusually low, for the pounds of coal per I.H.P. per hour amounted to only 1.46 for the main engines and 1.445 for all machinery. See page 26 for the data for the four-hour trial.

After the four-hour trial the ship had the usual maneuvering trials, but these were unsatisfactory for the reason that the main-engine throttle valves were of poor design and could not be readily closed. These valves were ordinary unbalanced conical valves worked by knuckle-joint gear, and were closed against the pressure in the steam pipe. The valves closed rather easily from full opening to the .3 mark, they were hard to close from .3 to .1, and to close the valve completely it took three strong men at the throttle-valve wheel with a 21-inch monkey wrench to increase the leverage. These throttle valves have been replaced by balanced valves, so that, as far as the throttle valves are concerned, no further trouble is expected in stopping and reversing the engines.

On the afternoon of December 22d the *South Dakota* got under way for San Francisco and anchored off the Union Iron Works the next morning. Altogether, the trials of the *South Dakota* were a great success. The ship was four days away

from the works of her builders, and in that time she steamed 780 miles from San Francisco to Santa Barbara and return, and performed most satisfactorily at both the standardization and four-hour full-power trials. This short time on a trial trip is an unusually fine record. Judging from the way she steamed and the way the machinery performed, it is safe to say that the *South Dakota* could have made much better speed had the engineer cared to drive her. A bonus for increased speed would have made her faster, and a forfeit for using water on the bearings might have kept it off.

The post trial inspection of the *South Dakota* at the Union Iron Works by the Engineering Trial Board showed only minor defects, the most serious of which (the main throttle valves) has already been noted. The main-engine cylinders, pistons and valves were in good condition, and the metallic packing of piston rods and valve stems was fine. The bearings were in very good condition, and only slight dragging of the babbitt was noticed in a few of the main bearings and crank-pin bearings, not enough to interfere with the free passage of oil through the oil grooves. The rod of the S.F.L.P. slide-valve balance piston was found to be broken. As this rod is one with the slide-valve stem a new stem has been fitted. The boiler tubes were found to contain some dirt and mill scale, but otherwise the boilers were in good shape. The auxiliary machinery was in excellent condition except that one of the cast-iron supporting brackets of the blower-engine cylinders over boiler Q was broken. The break has since been repaired.

PERFORMANCE.—FOUR-HOURS' OFFICIAL TRIAL.

DECEMBER 22, 1906.

*Steam Pressures.* (*Average of one-half hourly observations.*)

| | *Starboard.* | *Port.* |
|---|---|---|
| Mean steam pressure at boilers, pounds | 278.4 | |
| engines, pounds | 259.2 | 259.7 |
| H.P. steam-chest gauge, pounds | 238.6 | 237.5 |
| 1st receiver (absolute), pounds | 126.9 | 127.1 |
| 2d receiver (absolute), pounds | 58.1 | 56.0 |
| Vacuum in condensers, inches of mercury, mean | 26.28 | 26.7 |

*Temperatures.* (*Average of one-half hourly observations.*)

| | Starboard. | Port. |
|---|---|---|
| Injection, degrees | 58.1 | 60 |
| Discharge, degrees | 110.0 | 108.4 |
| Hotwell, degrees | 104.0 | 108.5 |
| Feed water, degrees | 168.7 | 181.2 |
| Engine room, working platform, degrees | 77.5 | 77.5 |
| Firerooms, working level, degrees | 88.7 | 88.7 |
| Smoke stacks, average, degrees | 582 | |

*Revolutions, or double strokes, per minute.* (*Average of one-half hourly observations.*)

| | | |
|---|---|---|
| Average revolutions, main engines, per minute | 125.58 | 124.88 |
| Mean revolutions, both engines, per minute | 125.23 | |
| Pumps, main air | 14.87 | 17.0 |
| circulating | 171.0 | 165.0 |
| feed, d.s., per minute | 24.0 | 23.0 |
| fire and bilge | 22.8 | 46.2 |
| dynamo condenser, air and circulating | 21.8 | |
| Dynamos | 350.0 | |
| Blower engines | 384.8 | |
| Speed of ship, in knots per hour | 22.24 | |
| Slip of propeller, in per cent. of its own speed, based on mean pitch | 16.53 | 16.07 |
| Air pressure in firerooms, in inches of water, mean | 1.35 | |

*Mean Effective Pressures in Cylinders, in pounds per square inch.* (*Averages of cards taken at half-hourly periods.*)

| | | |
|---|---|---|
| Main engines, H.P. cylinder | 94.94 | 96.88 |
| I.P. cylinder | 45.77 | 46.72 |
| F.L.P. cylinder | 25.9 | 24.6 |
| A.L.P. cylinder | 25.25 | 22.2 |
| Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons | 55.187 | 53.44 |

INDICATED HORSEPOWER.

| | | |
|---|---|---|
| Main engines, H.P. cylinder | 3,282.7 | 3,331.3 |
| I.P. cylinder | 4,373.91 | 4,439.4 |
| F.L.P. cylinder | 3,403.8 | 3,168.4 |
| A.L.P. cylinder | 3,284.45 | 2,875.0 |
| total | 14,344.86 | 13,814.1 |
| Collective H.P. of both main engines | **28,158.96** | |
| Air pumps, main | 9.5 | 11.0 |
| Circulating pumps, main | 56.0 | 54.0 |
| Feed pumps, main | 133.2 | 120.5 |
| Dynamo-condenser, air and circulating pumps | 5.2 | |
| Fire and bilge pumps | 1.7 | 4.0 |

| | |
|---|---|
| Forced-draft blowers | 181.0 |
| Dynamo engines | 101.0 |
| Total | 677.1 |
| Collective I.H.P. main engines, air, circulating and feed pumps | 28,548.16 |
| Collective, main and auxiliary engines in operation | 28,842.81 |

COAL.

| | |
|---|---|
| Kind and quality used on trial | Harris Navigation, good quality. |
| Pounds, per hour, main and auxiliary engines, during trial | 42,180.0 |

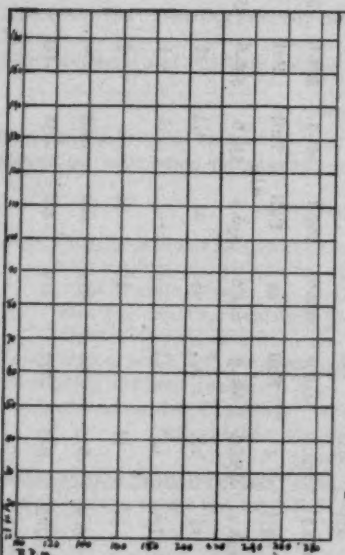
DEDUCED DATA.

| | |
|---|---|
| I.H.P. (total) per square foot of grate surface | 18.027 |
| main engines, air, circulating and feed pumps, per square foot of grate surface | 17.84 |
| main engines, air, circulating and feed pumps, per square foot of heating surface | 0.402 |
| Pounds of coal per I.H.P. per hour, collective, main engines, air, circulating and feed pumps | 1.47 |
| Pounds of coal per I.H.P. per hour, all machinery in operation | 1.445 |
| square foot of grate surface, per hour | 26.36 |
| heating surface, per hour | 0.593 |
| Cooling surface (main condenser), square feet per I.H.P. (total) | 0.997 |
| Heating surface, square feet per I.H.P. (total) | 2.519 |

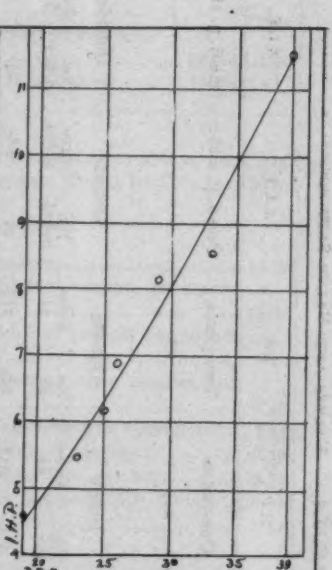
**Table I.**—U. S. S. *SOUTH DAKOTA.*—VALVES AND VALVE SETTINGS.

| | H.P. | | I.P. | | F.L.P. | | A.L.P. | |
|---|---|---|---|---|---|---|---|---|
| Number and type of valves | One-piston | | Two-piston | | One-d. p. slide | | One-d. p. slide | |
| Diameter of valves, inches | 24½ | | 27 | | ..... | | ..... | |
| Travel of valve, inches | ..... | | ..... | | ..... | | ..... | |
| Side of valve on which steam is taken | Inside | | Outside | | Outside | | Outside | |
| Width of port, and length of slide valve, inches | *Top.* 4½ | *Bottom.* 4½ | *Top.* 4½ | *Bottom.* 4½ | *Top.* 8–67½ | *Bottom.* 8–67½ | *Top.* 8–67½ | *Bottom.* 8–67½ |
| † Steam opening, linear, inches | 3 1/16 | 3 1/16 | 2⅜ | 2 1/16 | 2⅛ | 2 5/16 | 2⅛ | 2⅛ |
| Steam opening, area of, in square inches | 266.7 | 258.2 | 435.0 | 444.6 | 285.2 | 344.3 | 302.1 | 335.8 |
| † Exhaust opening, linear, inches | 3 1/16 | 4 | Full | 4½ | Full | Full | Full | Full |
| Exhaust opening, area of, in square inches | 258.2 | 270.8 | 680.5 | 624.6 | 536.6 | 536.6 | 536.6 | 536.6 |
| † Steam lap, inches | 1⅛ | 1½ | 2 5/32 | 2½ | 2⅛ | 2 1/16 | 2⅛ | 2 5/16 |
| † Exhaust lap, inches | 1 5/16 | 1½ | 17/32 | 21/32 | —½ | 7/16 | —⅛ | 7/16 |
| † Steam lead, linear, inches | 1/16 | 1/16 | 1 | 3/32 | 1/16 | 1 | 1/16 | 1/16 |
| † Cut-off in decimal of stroke, Maximum | .909 | .875 | .792 | .674 | .661 | .565 | .667 | .573 |
| † Cut-off in decimal of stroke, Minimum | .725 | .625 | .552 | .419 | .422 | .338 | .445 | .344 |

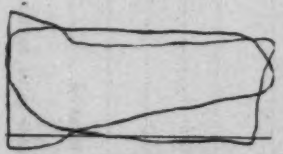
†To be taken from finished work.




MAIN CIRC PUMPS
RECIPROCATING ENGINE
9" – 17" X 12"



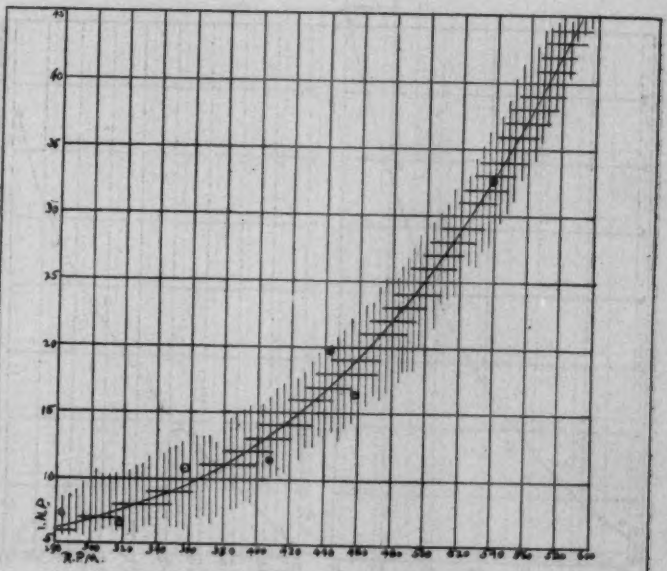

AUX AIR AND CIRC PUMP
VERTICAL SINGLE ACTING AIR & DOUBLE ACT CIRC
8"-14"-12" X 12"
(DYNAMO ROOM)



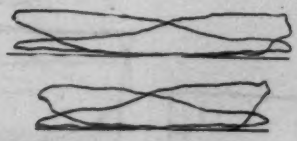
| | H.P | L.P. |
|---|---|---|
| R.P.M. | | |
| AUX STEAM PRESS | | |
| VACUUM | | |
| M.E.P. (MEAN) | | |
| INDICATOR SPRING | | |
| I.H.P. OF ENG | | |
| TOTAL I.H.P. | | |

| | |
|---|---|
| R.P.M (DOUBLE STROKE) | 29 |
| AUX STEAM PRESS | 125# |
| VACUUM | 23½" |
| M.E.P (MEAN) | 4.16# |
| INDICATOR SPRING | 40# |
| I.H.P. OF PUMP | 8.12 |

**Plate I.**

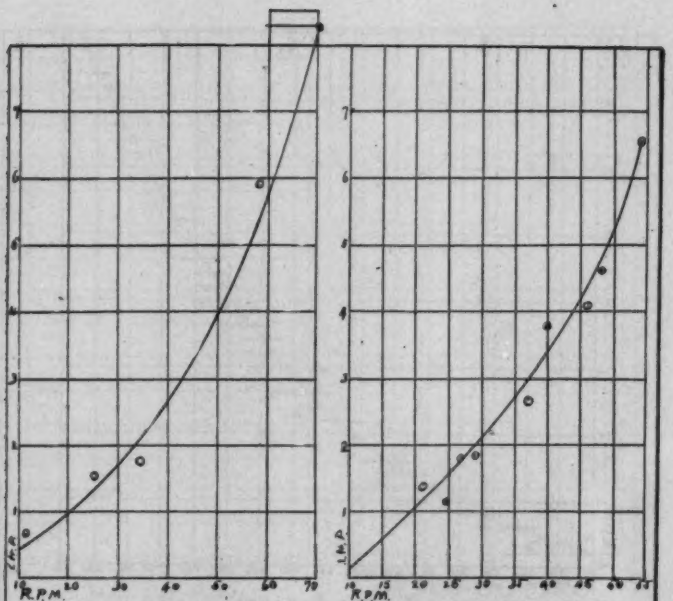


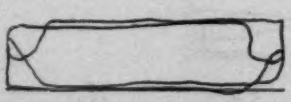

BLOWER ENGINES
5"-8" X6"

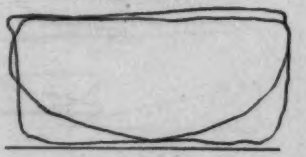


| | H.P. | L.P. |
|---|---|---|
| R.P.M. | 460 | 460 |
| AUX STEAM PRESS | 185# | 185# |
| VACUUM | 25" | 25" |
| M.E.P (MEAN) | 40.37# | 20.65# |
| INDICATOR SPRING | 100# | 40# |
| I.H.P OF ENG | 11.3 | 15 |
| TOTAL I.H.P. | 26.3 | |

**Plate II.**

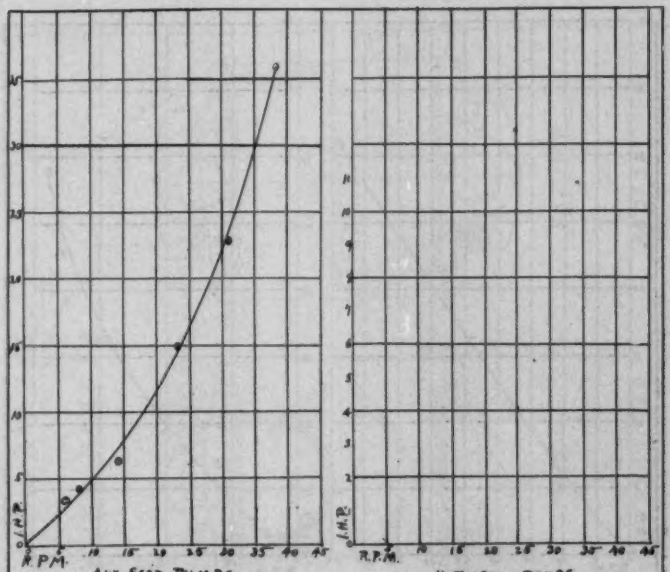


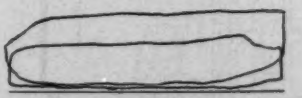





| | | | |
|---|---|---|---|
| R.P.M. (DOUBLE STROKE) | 43 | R.P.M. (DOUBLE STROKE) | 36 |
| AUX STEAM PRESS | 260# | AUX STEAM PRESS | 135" |
| VACUUM | 26" | VACUUM | NONE |
| M.E.P (MEAN) | 13.12# | M.E.P. (MEAN) | 34# |
| INDICATOR SPRING | 20# | INDICATOR SPRING | 20# |
| I.H.P. OF PUMP | 38 | I.H.P OF PUMP | 306 |

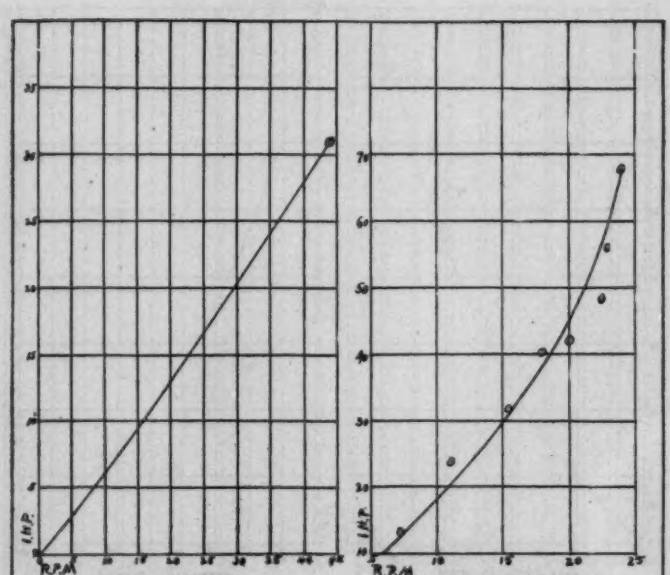
**Plate III.**

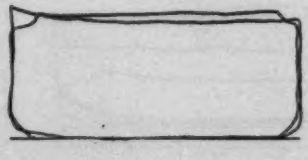


| | | | |
|---|---|---|---|
| R.P.M. (DOUBLE STROKE) | 23 | R.P.M. (DOUBLE STROKE) | |
| AUX STEAM PRESS | 230# | AUX STEAM PRESS | |
| VACUUM | 21" | VACUUM | |
| M.E.P. (MEAN) | 96# | M.E.P. (MEAN) | |
| INDICATOR SPRING | 150# | INDICATOR SPRING | |
| I.H.P. OF PUMP | 149 | I.H.P. OF PUMP | |

**Plate IV.**





| | | | |
|---|---|---|---|
| R.P.M. (DOUBLE STROKE) | 20 | R.P.M. (DOUBLE STROKE) | 15 |
| AUX STEAM PRESS | 240# | AUX STEAM PRESS | 236# |
| VACUUM | 26" | VACUUM | 23" |
| M.E.P (MEAN) | 33.1# | FEED PRESSURE | 300# |
| INDICATOR SPRING | 150# | M.E.P. (MEAN) | 134.8# |
| I.H.P OF PUMP | 127.6 | INDICATOR SPRING | 100 # |
| | | I.H.P. OF PUMP | 28.6 |

**Plate V.**

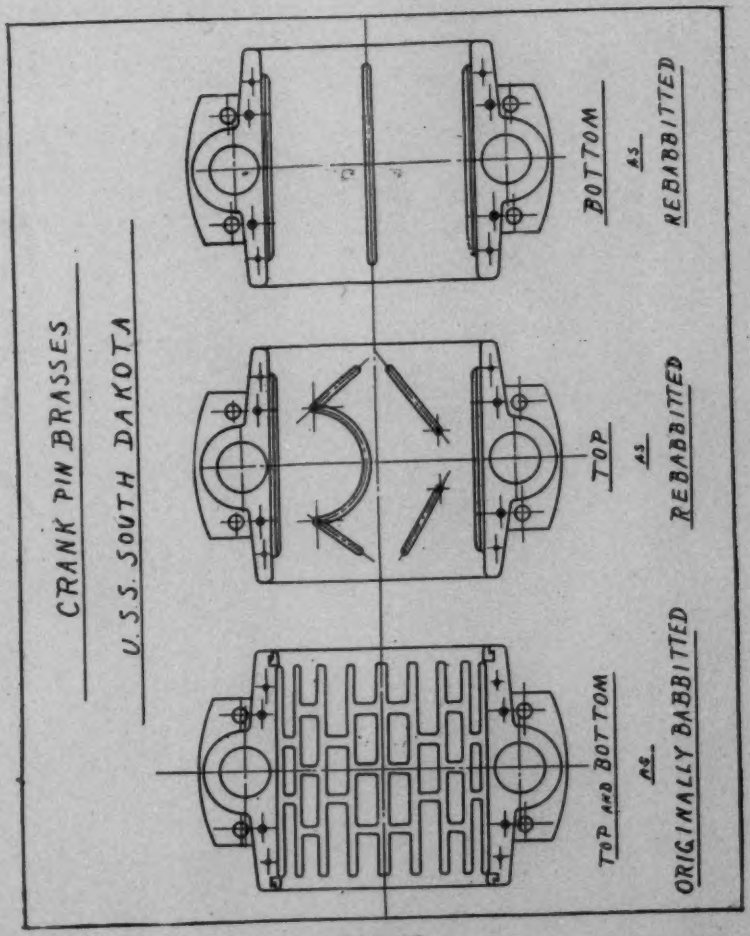

CRANK PIN BRASSES
U.S.S. SOUTH DAKOTA
TOP AND BOTTOM
AS
ORIGINALLY BABBITTED
TOP
AS
REBABBITTED
BOTTOM
AS
REBABBITTED

Plate VI.

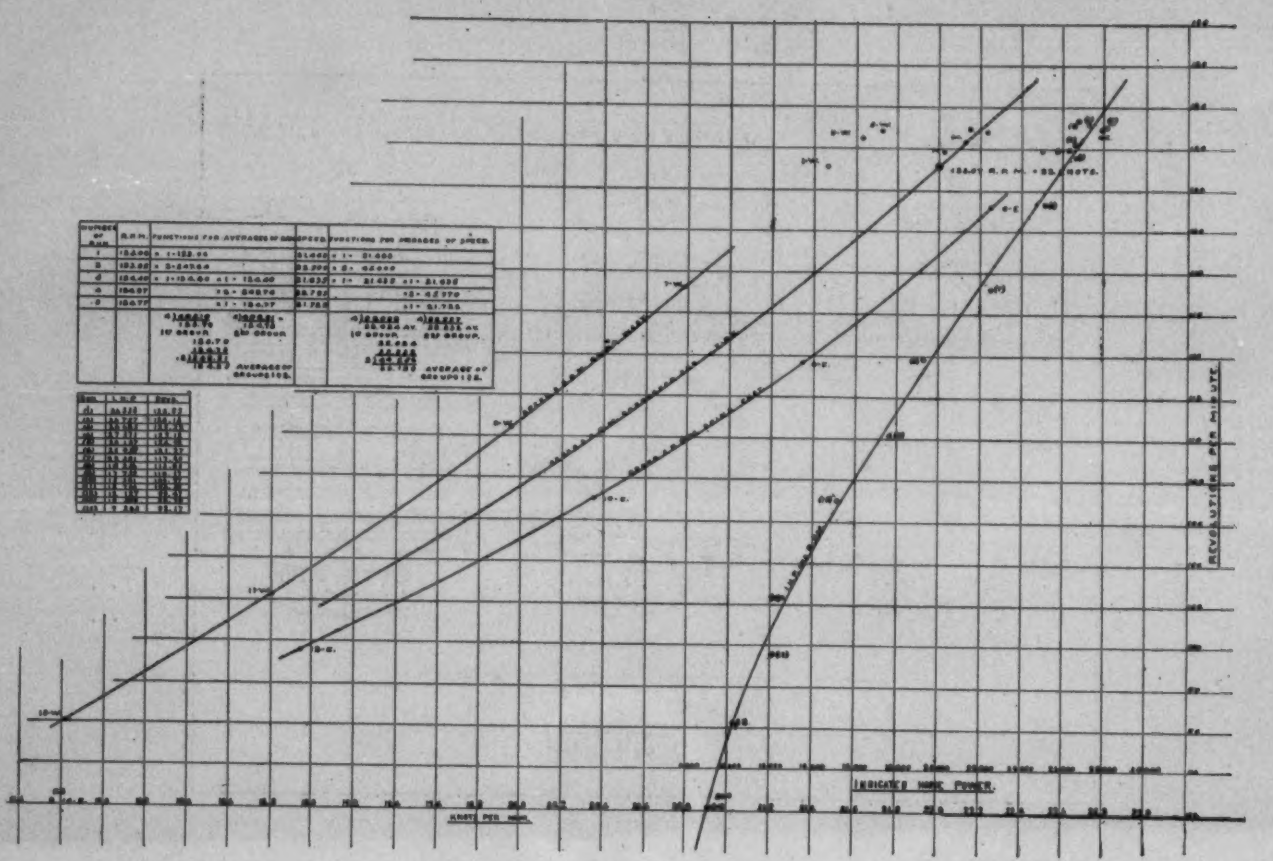


Plate VII.

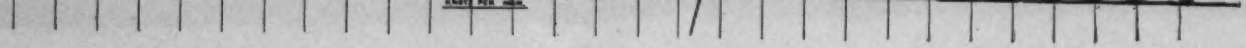
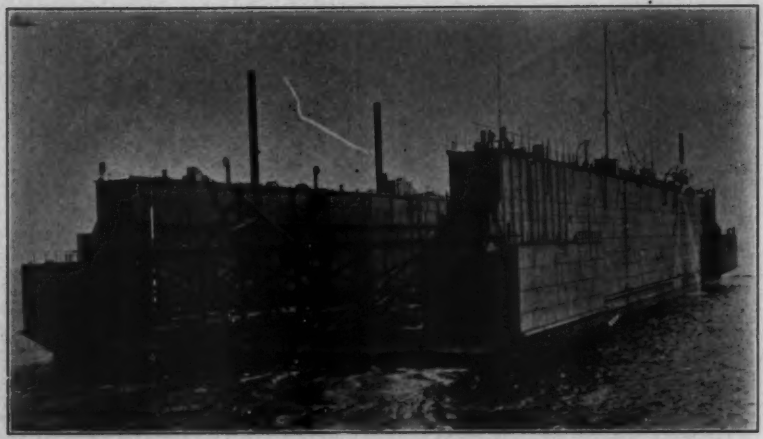


Plate VII.



CAVITE DRY DOCK.

# THE CAVITE DRY DOCK AT SEA.

By Commander F. M. Bennett, U. S. N. Member.

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The steel floating dry dock built at Baltimore for use in the Philippine Islands has been fully described by articles in previous issues of this Journal, from which articles I borrow the name, though I think it a misfit, because the water is so shoal in Manila Bay that this dock could not be used anywhere in the immediate vicinity of the U. S. Naval Station at Cavite. The act of Congress authorizing its construction is, I believe, the authority for fixing the name Cavite upon it. When launched, the dock was christened *Dewey*, in honor of the Admiral of the Navy, but in long association with it we of the towing squadron always found it awkward to apply that distinguished name to it, or, indeed, to use any name for such a remarkable object, and in daily conversation "it" and "the dock" were the more usual and milder terms by which it was designated.

The last chapter in the history of this dock that has appeared in the pages of the Journal was, I think, the article by a member describing the self-docking tests that were successfully carried out during the month of July, 1905, in the Patuxent river. Beginning from that point, I shall endeavor to describe briefly some of the engineering problems that arose while the dock was in transit from the United States to the Far East. Preliminary to such description, however, it is necessary to give some account of the special equipment of the dock and the towing ships to fit them for the work they had before them. At the conclusion of the self-docking tests the dock was pronounced a complete success, and so it probably was if it could have remained at its moorings in the Patuxent river and been used there for docking ships. As a

sea-going structure it was at that time far from complete, and as the long sea voyage was a compulsory service at the beginning of its career, its success at the time referred to cannot be regarded as complete when provision for that first service had been overlooked. Such important essentials as anchors and chains and a capstan for handling them, life boats, and running lights for a vessel underway, had to be provided, besides many minor but necessary articles and fittings before the dock could be safely moved. When the builders' men left the dock, only a few days before we intended taking it to sea, it was discovered that the shovels in use in the fireroom actually belonged to them, and that none had been provided for the dock, which incident may give an idea of the many little omissions that came to light to distract us during the hurried work of preparation for the long sea voyage.

The shape of the dock was very unfavorable for towing, the submerged section being rectangular and presenting a square, wall-like surface from seven to ten feet in depth and 135 feet wide to be dragged bodily through the water. In good, smooth weather and without aid from wind or currents we found four and one-half knots to be about the maximum speed we could make with the combined power of the towing ships, which speed also was about the limit that the towing gear could stand. More powerful ships could have pulled more, of course, but any rise in speed would have been met by such increased resistance from the dock that very much stronger towing lines than any we had would have been necessary. In one of the articles published in the JOURNAL there were drawings showing several designs of floating docks that had been submitted in competition when proposals for building this one were invited. At least one of these, if I remember correctly, showed a dock with the ends pointed, to facilitate its being towed at sea, and it seems, in view of the long journey ahead of the Cavite dock, that some such feature should have been included in its design. The large Havana dock, I have been told, was provided with a false, pointed

bow when it was towed out, and also with an enormous rudder, both of much value in keeping it manageable.

Our greatest troubles in the towing expedition may be directly charged against the unyielding opposition to progress of the square-fronted dock; it was a sufficiently ugly thing to tow in good weather, but in high head winds and seas, of which we encountered more than our share, it frequently took charge beyond any power to control. On such occasions the seas and the dock gave a very good presentation of that cataclysm upon which young engineers frequently speculate, which is supposed to result from the collision of an irresistible force with an immovable object, the dock playing the part of the immovable object with temporary success but with ultimate failure in all cases. Broken tow lines, the dock adrift, and a great amount of time and labor demanded to get hold of it again were the results. On some, if not all, of these occasions of disaster I am sure we could have retained hold of the dock had it been provided with a sea-going bow, but as it was, the great seas beating upon the square front of the dock drove it backward and put a strain upon our towing gear that could not be withstood. A pointed bow, also, would have enabled us to make the voyage to the Philippines at considerably greater speed, with corresponding reductions in time, and in cost of coal and towing gear consumed.

The vessels selected for the expedition were the supply ship *Glacier*, the naval colliers *Brutus* and *Caesar* and the tug *Potomac*. The *Glacier* and *Potomac* were manned by naval officers and crews and the colliers by merchant officers and crews. The principal dimensions of these vessels are: *Glacier*, 7,000 tons displacement, 353 feet length, 46 feet beam, 25 feet draught, 4,000 horsepower, 12.5 knots speed; *Brutus*, 6,600 tons displacement, 329 feet length, 41 feet beam, 23 feet draught, 1,200 horsepower, 10 knots speed; *Caesar*, 5,000 tons displacement, 322 feet long, 44 feet beam, 21 feet draught, 1,500 horsepower, 10 knots speed; *Potomac*, 785 tons displacement, 139 feet long, 28 feet beam, 12 feet draught, 2,000 horsepower, 16 knots speed. In actual towing in aver-

age weather the *Glacier* developed (by indicator) about 1,700 horsepower, the *Brutus* 1,100 and the *Caesar* 1,200, or 4,000 in the aggregate for the three ships, the combined displacements of which were more than 18,000 tons. This seems small power to move so much weight and have anything left to apply to towing a 12,000-ton dry dock, and so it was; but, all things considered, the vessels were better suited for the work than higher-powered cruisers or battleships would have been. Capacity for carrying coal for long periods at sea was a consideration that led to the selection of the colliers, and the demand for provisions for the expedition for a long period selected the *Glacier*, which ship has cold-storage space for 1,000 tons of frozen meats. The fuel question was met in her case by filling her cargo holds and part of the cold-storage space with 2,000 tons of coal. Besides providing cargo coal to burn when the bunker supply ran low, these cargoes were necessary with all the ships to keep them deep in the water and their screws submerged for effective operation. The towing ships were all single-screw vessels, which was their weakest point, as they were clumsy and hard to manage at times when handiness would have been a great comfort.

Except the *Potomac*, none of these ships had any special appliances for towing, and all had therefore to be prepared after their selection for the expedition. The chief item in this preparation was the installation of a towing machine on each vessel. The machines obtained were those made by the American Ship Windlass Company of Providence, R. I., and were the size designated as No. 5, the largest that is made except on special orders. This machine is a two-cylinder steam engine, the crank shaft of which, through a pinion and drum gear, drives a large drum upon which the wire tow line, two inches in diameter and 1,200 feet long, is reeled. The ratio of the gearing is 5 to 1; the steam cylinders are 16 inches in diameter and 16 inches stroke of piston. Steam is always on this engine when towing, being admitted through a partly-open regulating valve, and its distinctive feature is in providing this steam cushion to take up any sudden jerks on the

tow line. When any increased strain comes on the line, it is drawn out against the pressure of the steam in the cylinders, an automatic attachment at the same time screwing open the regulating valve until a sufficient increased pressure is admitted to the cylinders to balance the strain on the line. Then, when the strain becomes normal again, the machine slowly winds in the few fathoms of wire that ran out, the automatic gear closing the regulating valve at the same time until equilibrium between steam pressure and strain on the line is reestablished. So well did the machine work that a mark on the line always came back to within a few inches of its original place. In rough weather, with the ships pitching and wallowing deeply and the strain on the tow line consequently very variable, the machine would be working constantly, paying out wire violently and reeling it back gently, but in fairly smooth weather it would sometimes stand for hours at a time without a movement. A by-pass valve and operating lever are provided for working the machine independently of the automatic gear.

Like most vessels built for commercial purposes, the towing ships all had the hand wheel and hand-steering gear on the upper deck as far aft as the taffrail, and these were directly in the way of the tow lines. On board the colliers the difficulty was met by shifting the wheel to the deck below, connecting it to its former spindle by sprocket wheels and chain, and by building heavy timber casemates over the gear remaining on the upper deck. On board the *Glacier* two deck houses far aft made the problem more difficult, and it was solved eventually by erecting across the after deck three heavy steel-and-oak arches over which the tow line was led clear of the houses and the hand wheel. This was not a good arrangement, as the wire hawser had to lead up from the towing drum to pass over the arches, and, of course, down again toward the water when it left the aftermost arch. With the great strain upon it, the wire would cut into the hard oak tops of the arches as it worked back and forth, and kept us busy patching and repairing them. There was, fortunately, a quantity of quar-

ter-inch sheet copper on board, and we discovered that that made an excellent covering for the arches in the wake of the tow line; it would get cut through in the course of a week or so, but that was a great improvement over having to piece and patch on the frames every day. I never knew before how tough so soft an appearing metal as copper is, as it certainly stood more punishment from the tow line than could iron or steel plates of the same thickness. If any scientific member of this Society doubts this statement I invite him to attack a soft piece of copper with a file or with hammer and chisel and he will learn something new.

Twelve steel hawsers, of the size denominated six-inch, but rather more than two inches in diameter, were provided for use with these machines. They were each 200 fathoms (1,200 feet) long, weighed about 7,000 pounds each, and were fitted with a thimble and shackle in one end, the other end being pointed to pass through a 2-inch hole in the flange of the towing drum, where it was secured by clamps. Four of these were given to each of the three towing ships. Big as they were, they were found insufficient for the heavy strains that mid-winter Atlantic weather put upon them, and at the first opportunity 8-inch Bullivant steel hawsers, obtained from England, were substituted for them. Four of the 6-inch wires were made by the Roebling Company in the United States; the other eight came from England.

Twelve 15-inch manila hawsers were also provided. These were 200 fathoms long and were very big, handsome lines when new, weighing five tons each. Five of them were doubled by joining the ends and fitting thimbles in the bights thus formed, the two parts of the line being stopped together every two fathoms the whole length by stout seizings of ratline stuff. As thus made up, each of these spans with its thimbles, shackles and seizings weighed over six tons, and was, as may be readily understood, an awkward thing to handle, particularly after it had been in use for towing and had become thoroughly waterlogged. The other seven 15-inch lines were left single, with an eye for a towing thimble in one

end only. The shackles, thimbles and other fittings for all these lines were made in the equipment shops at the Boston Navy Yard, and were enormous for such things, as may be realized by looking at Plates 1 and 2 accompanying this article. In distributing these manila towing spans for use, two of the double and one of the single ones were put on the dock, and one double and two single spans on each of the three ships. The dock was provided with four bridles, each 90 fathoms long, made of 2½-inch chain cable, the legs securely bitted at opposite corners of the dock, and a towing span shackled in the middle where the legs joined. Two bridles were kept in place at each end of the dock, and at the end not in use (the stern for the time being) a towing span was kept shackled to the bridle and ranged ready for running at any time; this to save time in taking the dock in tow after a breakdown. We towed the dock from either end indiscriminately, whichever one was the easiest to get hold of under the existing circumstances. To make this possible, a wooden trestlework-bridge and derrick for handling the heavy bridles and towing spans had been built at the stern end of the dock as an afterthought while we were preparing to take it to sea.

The expedition started from the Patuxent River December 28, 1905, and passed out at the Capes of the Chesapeake about 10·30 P. M. the 29th. The *Brutus* was next the dock and had two of the double manila spans, shackled end to end, between the 6-inch wire on her towing drum and the bridle on the dock. The *Caesar* was next ahead of the *Brutus*, with one double 15-inch span shackled into the end of the wire on her drum, the other end being fast on the bow of the *Brutus* by a chain bridle dipped through its shackle. In getting underway, and for several days thereafter, the *Potomac* towed ahead of the *Caesar*, but her coal capacity did not permit of continuous work of this kind, and the permanent arrangement was with the *Glacier* ahead of the *Caesar*, the *Potomac* being in tow herself astern of the dock. For several thousand miles at first the *Glacier* towed with one of the long 15-inch

single manila spans between her 6-inch wire and the bow of the *Caesar*, but after that had been carried away twice and cut several times in emergencies she used a double span, the same as the other ships. In open water all the ships kept nearly all of their 6-inch wire hawsers unreeled from the towing engine, which made the tow considerably more than a mile long from the bow of the *Glacier* to the stern of the *Potomac*.

The first check from bad weather occurred January 4, when we were only about 500 miles along on our journey. A moderate gale from S.S.W. and heavy sea prevailed at the time. The two colliers were fast to the dock and were facing the weather, steaming ahead only enough to keep steerage way, but their violent plunging combined with the beating of the heavy seas against the dock distressed the towing engines greatly, notwithstanding the long tow-lines in use. About the middle of the afternoon the *Caesar's* machine was disabled, several teeth breaking out of the drum gear and catching between the gear and the pinion on the crank shaft where they caused the crank shaft to be lifted out of its bearings, breaking the caps, and, of course, putting the machine out of action. They managed to bitt the line, and thus held on without losing it, and always thereafter the *Caesar* towed with her line bitted, being convinced that the towing machine was inadequate to the work of our expedition. The drum gear was temporarily repaired by putting in studs in place of the broken teeth and thus made serviceable for paying out or reeling in slack wire. The teeth of the drum gear were not machined parallel, but were slightly tapered lengthwise, just as the pattern had been made, to permit of its being drawn out of the sand in molding. This was their source of weakness, as they engaged chiefly at the thicker ends, and therefore brought on an unequal strain that caused those ends to chip and break; this happened to the towing machines on all three ships to a greater or less extent and led to the complete disablement of the machines of the *Brutus* and *Caesar*.

About a week later, January 12, the dock broke adrift from us for the first time. The wind was only moderate, but a

very heavy sea had been running all day, causing the ships to roll abominably, and no good cause for the towing gear to fail existed; but late that night the 6-inch wire line in the train between the *Brutus* and the dock parted and let the dock go adrift. I shall not in this paper attempt to describe the toil and anxiety that such an accident brought with it, but they may be readily imagined by anyone reflecting upon the mass and weight of wet lines to be hauled on board, the clearing and preparation of them for use again, the handling of heavy shackles in the dark, and then the task, sometimes really dangerous, of getting hold of the drifting and unmanageable dock. In the whole history of the expedition the dock was adrift six times—four times in rough seas, once in a calm when there was absolutely no provocation for it, and once as an incident of shortening the tow-lines preparatory to entering port. The parts of the towing gear that failed and thus permitted these accidents were the 6-inch steel hawsers, twice; a double 15-inch manila span, once; and once each for a 2-inch chain bridle, a double shackle and a triangular shackle. Only a few days after we had resumed towing after the breakdown above mentioned, the single 15-inch manila line between the *Glacier* and *Caesar* parted, but we did not reckon that a calamity, because two ships remained towing the dock and the general progress was not stopped while the *Glacier* repaired damages. The same thing happened again at a later period in the voyage, after which the use of the single 15-inch lines was discontinued.

Beginning January 24 we had a period of almost a month of head winds and discouraging conditions generally. We were about the middle of the Atlantic Ocean trying to make a course east (true) along the 28th parallel of latitude, and met the wind from N.E., East, and S.E., almost without change and of such force as to impede us greatly, while frequent gales gave us a vast amount of hard labor and trouble. Daily "runs" of less than forty miles became common, and one day the noon position by observation put us twenty-four miles west, or astern, of the place we had been in the previous

noon. January 25, while facing a moderate to fresh gale from S.E., the *Glacier* had to cut off from the tow to reduce the strain on the lines of the other ships, but that night the great strain and heavy sea overcame the towing machine on the *Brutus*, which was totally disabled. Teeth were stripped off the drum gear around almost half its circumference, the crank shaft was thrown out of its bearings and bent, both connecting rods badly bent, and other parts either broken or bent beyond repair; the 6-inch wire line parted near the towing drum at the same time, and of course the dock was adrift. The weather continued so bad that it was forty-nine hours before we got the dock in tow again, during which time it had drifted about 100 miles back toward the United States. Only twenty-nine hours later it broke adrift again by the parting of a 2-inch chain bridle over the stern of the *Brutus*, and was at large a day and a half before lines were gotten to it and the towing hawsers hauled over ready to use.

In the accidents that had happened thus far the longest pieces of the broken 6-inch wire lines had been hauled on board the dock, and these were spliced together, making one span about 250 fathoms long, which was put into the place of a damaged 100-fathom 15-inch manila span between the *Brutus* and the dock, the forward end of it being shackled into a new 6-inch wire line on the *Brutus*. This line, owing to the *Brutus*' towing machine being disabled, was nearly all paid out, the inboard end being bitted and the bitts backed to the mainmast by chain cables taken from the anchors. There was thus a clear run of tow lines of over 3,200 feet, or more than half a mile, from the *Brutus* to the dock, the great length and weight of which was its own protection, and there were no more breakdowns as long as it was in use. As made up this time, the whole length of the tow from the *Glacier* to the *Potomac* was more than a mile and a half.

While toiling forward against head wind and seas with enough troubles of her own, the exigency of the *Potomac* in regard to coal began to force uncomfortable attention. As before stated, that vessel was usually towed, but in very rough

weather she had to cast off and take care of herself, and consequently had to keep enough coal on hand to enable her to weather a gale, besides sufficing for her daily needs. We watched her noon reports showing the steady diminution of her supply from day to day and hoped fervently for a let-up in the merciless wind that would make it possible for her to come alongside the *Glacier;* but no such abatement came nor seemed probable, until finally, when the situation forbade any more waiting, the *Glacier* cast off from the head of the line and devoted herself to the *Potomac* for the next six days. At first we took her alongside and gave her fifteen tons of coal in about half an hour, but then had to desist, as the sea was so heavy that both vessels were sustaining serious damages. Nearly a day was spent in trying to put into operation an overhead wire transporter, but the violent motion of the ships, the pitching of the *Potomac* especially, rendered this scheme entirely impracticable. Then, with the *Potomac* in tow, we got an under-water line in operation and began sending her coal in bags, hauled through the water. That was slow at first, and during two days we gave her only about as much as she burned, but the next day, with experience and with much heavier gear to work with, we gave her four days' supply. The next morning the weather was moderate for a few hours, which we took advantage of to get her alongside, and gave her enough to make her safe for two weeks longer. It was a hard and trying week, but valuable in showing that men can do almost anything when they have to.

The dock had now become a source of anxiety because the people on board it thought it threatened to fall apart. The end pontoons were secured to the overhanging side walls of the central pontoon by a system of plates, angle irons and bolts, and weakness had developed in the riveted angle irons that secured the vertical fastening plates to the deck of the end pontoons. The dock was very buoyant and always had considerable motion, both rolling and pitching, in a seaway. This brought a constantly varying series of stresses and strains upon the riveted joints spoken of, which being continued for

weeks without rest as the dock pitched about in the rough sea began to show disastrous results. Many of the rivets were worked loose (6,000 out of 7,000 had to be renewed), and this loosened the angle irons so that they had considerable play as the ends of the dock rose and fell, the mischief, of course, multiplying as the amount of loose motion increased. There was yet strength enough in the joints to resist considerable bad weather, but it was not prudent to let the injuries go on increasing, and the commander of the expedition decided to seek the nearest port where repairs could be made. Accordingly we went to Las Palmas, in the Canary Islands, and there had the dock strengthened so that it was more seaworthy than when we left home with it. But for this work I fear we would have lost the dock, as soon afterward we had a gale in the Mediterranean sea worse than any we saw in the Atlantic, and which, I believe, would have taken the end pontoons off the dock had they been allowed to remain in their crippled condition.

When we arrived at Las Palmas we were just fifty-seven days from the Patuxent River, and had dragged the dock in that time 3,844 miles, or considerably more than the distance across the Atlantic could we have applied it to a direct course. Had it not been necessary to repair the dock we should have been obliged to stop at the Canaries anyhow, because our long period at sea had almost exhausted the supply of coal and water on the dock. We started with what was considered ample to reach Port Said, but the many breakdowns had caused the use of the capstans and other steam machinery on the dock much more than had been expected, and, as no condenser had been provided, a great amount of fresh water had been lost in the form of exhaust steam. There was an evaporator on the dock, but without a condenser for the steam that passed through it it is doubtful if it produced as much water as was required in the form of steam to evaporate the sea water in the first place. Some scholarly member of this Society familiar with thermal units and their habits may be able to cipher this out otherwise, but to an ordinary mind this peculiar form of an evaporator looks remarkably like a

device for making something out of nothing. At any rate, its use was discontinued when it became evident that it caused a loss and not a gain in the fresh-water tanks.

Having referred to people on board the dock, I will answer a question that has been asked me a number of times already, and say that there always were men on the dock when it was being towed at sea—more than thirty of them, in fact. There were nine men, employees of the Bureau of Construction and Repair, who constituted a permanent crew for the dock to attend to its care and operation when it reached its destination. Then there was a regular crew shipped for the voyage the same as the crew of any merchant ship, composed of sailing master, two mates, cook, steward, twelve seamen (afterward increased to eighteen), a rigger and a few others, such as messmen and telegraph operator. There was nothing perilous in their position; on the contrary, they were undoubtedly safer than they would have been on a real ship, and they were certainly more comfortable in rough weather than any of us were on the towing ships.

April 7 to 9, when in the eastern basin of the Mediterranean Sea about 200 miles east of Malta, we encountered a gale from eastward and southward that at one time reached the force of a whole gale (10 by the Beaufort scale) and raised a heavier sea than any that we had experienced in the Atlantic Ocean. The *Glacier*, as she had done on several previous occasions, cast off to reduce the strain on the tow lines, but the gale steadily grew in force, and the second day, April 8, the dock broke adrift by the parting of a large shackle that joined the legs of the towing bridle to the first span. The dock drifted rapidly to leeward broadside to in the trough of the sea and achieved her maximum roll on this occasion, only eight degrees, but owing to the great height of the side walls above the water this looked very much more to an external observer. As a lee shore was only 200 miles away the situation was more critical than when the dock was adrift in mid ocean, but after it had been loose twenty-three hours and while the sea was yet heavy the *Brutus*, aided by the *Potomac*, got a

line to it and was able to check drifting to leeward though unable to tow it against the weather. By the 10th the storm had blown itself out and we all resumed towing to the eastward. The evening of the 11th, when towing in a smooth sea with no wind, a double 15-inch manila span between the *Brutus* and the dock suddenly parted, from no cause whatever except what is popularly known as "pure cussedness," and set the dock adrift again. The situation offered no difficulties in picking up the dock, but the work of hauling in the heavy lines, ranging them clear for running, and running them again in making up the tow, kept us busy nearly all night, and it was after two o'clock in the morning before we were steaming ahead on the course again.

The passage of the dock through the Suez Canal was effected with less trouble than anticipated, and there would have been practically none had not an unusually strong beam wind forced it out of one of the sidings where it was moored and against the bank on the opposite side, blocking the canal for several hours. It was towed through by two powerful tugs of the canal company in tandem ahead, with the *Potomac* astern to push and to prevent the rear end from yawing into the banks. The dock was in the canal four and one-half days, but was actually under way only thirty-five hours, considerable periods having been spent at anchor in Lake Timseh at Ismailia and in the Great Bitter Lake to allow steamers to pass both ways and avoid stopping traffic. The *Potomac* rendered such excellent service here that it made up for all the trouble she had caused us in the Atlantic. She returned to the United States from Suez.

At Port Said we got the 8-inch steel hawsers that had been ordered from England, and the *Brutus* and *Caesar* put them on their towing drums in place of the 6-inch wires. In making up the tow at Suez the manila spans between the *Brutus* and the dock were discarded and their place filled by 105 fathoms of 2½-inch chain taken from the spare bridles on the dock. One end of this chain was shackled to the dock's bridle and the other into the end of the 8-inch wire from the

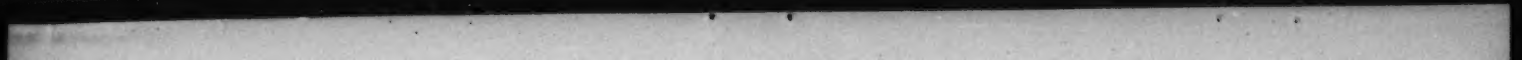
*Brutus*' towing drum. I neglected to state in the proper place that at Las Palmas we received from the United States spare drum gears for the towing engines, and those machines on the *Brutus* and *Caesar* were put in good order again. The weight of the chain span just described was fifteen tons and of the 8-inch wire joined to it almost five tons, the two forming a catenary so deep that there was no danger of any power we had ever bringing it up taut. The *Caesar* had a double manila span between her 8-inch wire and the *Brutus*, and the *Glacier* used another one to the *Caesar* from a new 6-inch wire on her towing machine. With the towing train thus strengthened we felt free to steam at full power, and did so with such excellent results that we towed the dock from Suez to Singapore, 5,000 miles, in forty-eight days, without a break or accident of any sort to the towing gear, and with only one stop, of two hours' duration, to replace a gasket blown out on the *Glacier*.

In entering the port at Singapore the combination of a very dark night and a swiftly-running spring tide threw the squadron into some confusion while shortening in the lines, and when the ships got straightened out clear of danger from each other the dock was found to be adrift. Contrary to all the rules of dynamics, the big double shackle joining the chain span to the dock's towing bridle had parted, but how it happened was not at all clear. The dock was anchored, and after daylight was gotten under way and towed into port with no greater loss than a few hours' time, but as it had taken us six months to get that far, time had become a matter of small value to us. A stop of a week was made at Singapore to coal and water the ships and to give the crews a run ashore. Then we resumed our voyage, proceeding northeastward into the China Sea, where the best long run of the whole trip was made, the distance of over 1,300 miles to Olongapo being made at the average rate of 112½ miles per day. The best day's run of the whole voyage was 152 miles, made June 9th in the Bay of Bengal, where a current of at least forty miles per day favored us; the worst day's run was, as before mentioned, in the Atlantic,

where we achieved *minus* 24 miles one day steaming against a head wind and sea. We arrived at Olongapo in Subig Bay early in the morning of July 10, 1906; the towing ships let go one after the other, the dock was anchored, and a few hours later we left it there without regret and returned to the world that we had been out of for more than half a year.

| Passages. | Miles made good. | Time. Days. | Hours. | Daily averages. |
|---|---|---|---|---|
| Patuxent River to Las Palmas, | 3,844 | 56 | 23 | 67.56 |
| Las Palmas to Port Said, . | 2,849 | 32 | 00 | 89.03 |
| Port Said to Suez, . . . | 87 | 1 | 11 | 58.78 |
| Suez to Singapore, . . . | 4,992 | 48 | 7 | 103.38 |
| Singapore to Olongapo, . . | 1,317 | 11 | 17 | 112.47 |
| Totals, . . . . . | 13,089 | 150 | 9 | 87.03 |

| Ship. | Coal consumed. Tons. | Cost of coal. |
|---|---|---|
| *Glacier*, . . . . | 5,136 | $27,224 |
| *Brutus*, . . . . | 3,664 | 12,594 |
| *Caesar*, . . . . | 3,238 | 14,164 |
| *Dewey*, . . . . | 923 | 4,088 |
| Totals, . . . | 12,961 | $58,070 |



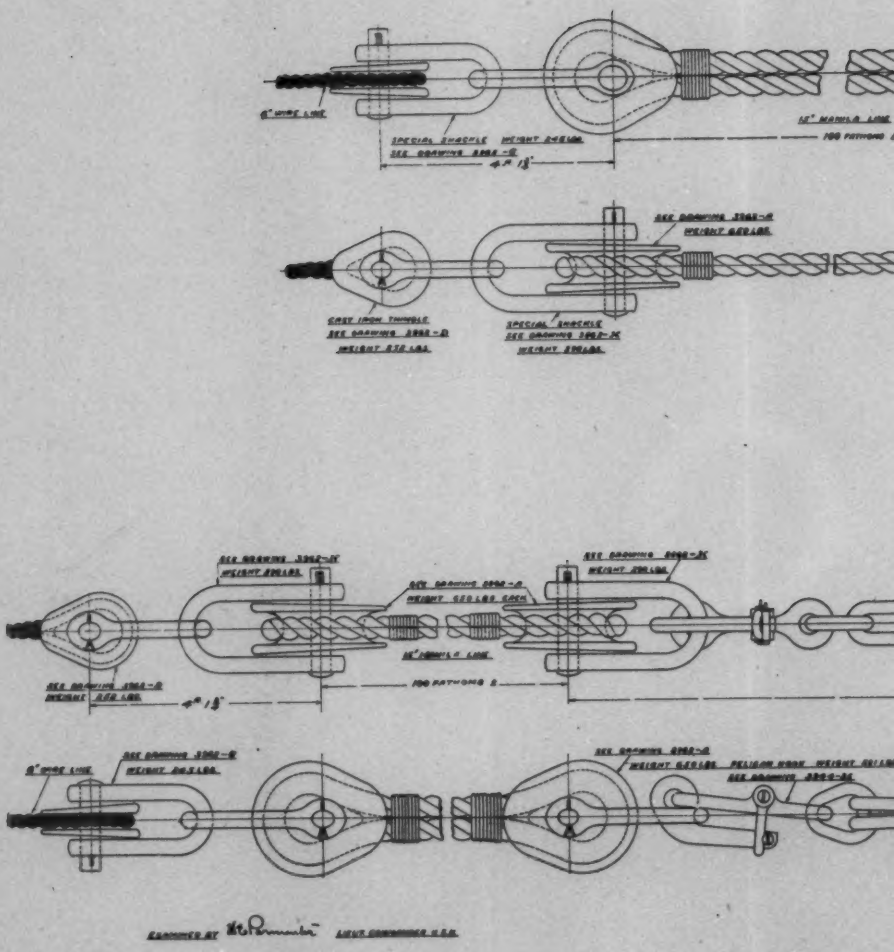
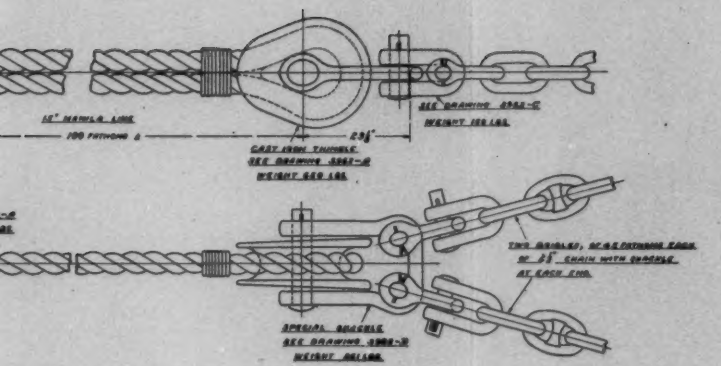
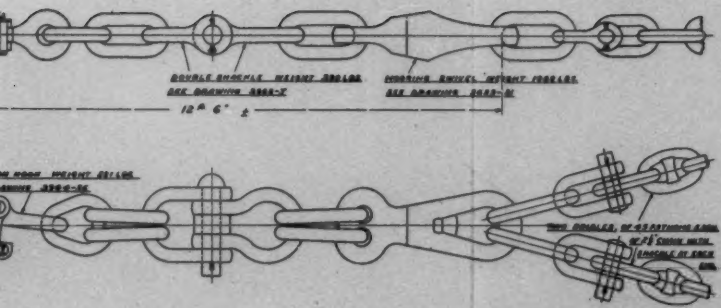


Plate I.







TOWING DEVICE FOR
U. S. DRY DOCK DEWEY
EQUIPMENT DEPT, U. S. NAVY YARD BOSTON.

APPROVED [signature] CAPTAIN U.S.N. DRAWN BY [illegible] NOV. 21, 1905
EQUIPMENT OFFICER. DRAWING NO. 3971-36.

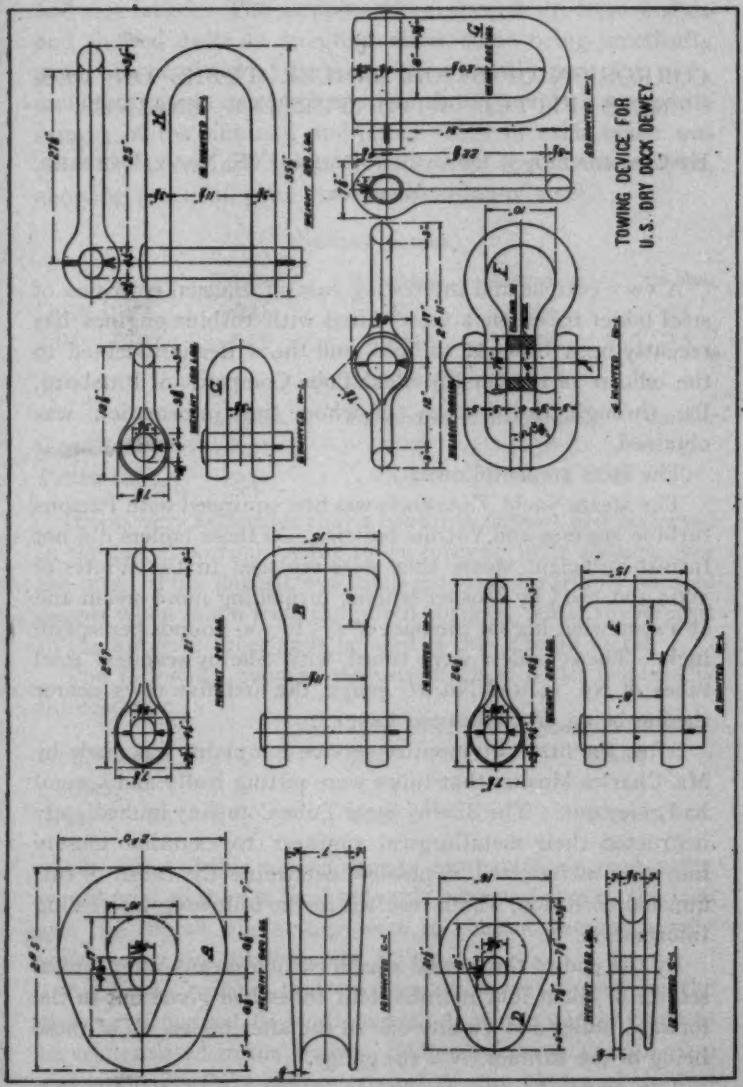



Plate II.—Details.

# CORROSION OF STEEL BOILER TUBES ON VESSELS FITTED WITH TURBINE ENGINES.

By Commander J. Edward Palmer, U. S. Navy, Retired, Member.

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A very curious and interesting case of unusual corrosion of steel boiler tubes on a vessel fitted with turbine engines has recently been brought to light, and the writer is indebted to the officers of the Shelby Steel Tube Company, of Pittsburg, Pa., through the courtesy of whom this information was obtained.

The facts are as follows:

The steam yacht *Tarantula* was first equipped with Parsons turbine engines and Yarrow boilers. As these boilers did not furnish sufficient steam they were replaced in the Winter of 1904 and 1905 by Mosher boilers, furnishing more steam and at a somewhat higher pressure of 275 to 300 pounds per square inch. These boilers were tubed with Shelby seamless steel tubes of No. 14 and No. 16 gauge, the first five rows nearer the fire being of the heavier gauge.

After the first two months' service complaint was made by Mr. Charles Mosher that tubes were pitting badly and several had given out. The Shelby Steel Tube Company immediately instructed their metallurgical engineer to examine closely into this matter, and if possible determine the cause of this unusual corrosion, which resulted in the following interesting information.

By the end of the second season (which means after a total service of about four months) four tubes had given out in the forward boiler and twenty-one in the after boiler, all of these being of the thinner (No. 16) gauge.

The owner having decided to retube, an opportunity was

given to examine the interior of a number of the tubes which had not failed. The samples when opened up from end to end showed quite an irregular effect, some being practically good, others pitted at certain places, mostly near the ends, and others again more or less pitted throughout. A composite sample of the unpitted and pitted tubes in each boiler was carefully taken and gave the following results on analysis, showing practically the same composition of steel.

FORWARD BOILER.

| | Sulphur. | Phosphorus. | Manganese. | Carbon. |
|---|---|---|---|---|
| Good tube, | .035 | .008 | .41 | .14 |
| Pitted tube, | .026 | .007 | .40 | .15 |

AFTER BOILER.

| | Sulphur. | Phosphorus. | Manganese. | Carbon. |
|---|---|---|---|---|
| Good tube, | .031 | .007 | .50 | .15 |
| Pitted tube, | .031 | .005 | .41 | .16 |

It was very noticeable that a brownish deposit had collected in the pitted portions of the tubes, forming little nodules over the pits. This deposit was analyzed, and invariably showed copper when taken from the pitted portions, while the deposit in the unpitted tubes gave no sign of this foreign metal.

The following average analysis of these boiler residues is interesting:

| | From after boiler. | From forward boiler. |
|---|---|---|
| Iron, | 51.20 | 58.06 |
| Copper, | 1.84 | .39 |
| Zinc, | None | None |

The effect of this copper, even in comparatively good water, would tend to start a local galvanic current between the iron and the copper where they were in contact, thereby slowly eating away the tubes in pits.

As it was evident that this corrosion was caused by the above, it remained to be discovered how this copper came to be accumulated in the boilers. After following carefully up every clue all the evidence pointed to the blades of the tur-

bine engines, which were made of a bronze containing a considerable percentage of copper. These blades were found to be eroded by the steam impinging on them at a very high velocity, and it is most probable that the copper was carried over by the steam (possibly with the aid of volatile acids) into the condensers, and from thence into the boilers and accumulating in the tubes.

The deposit found between the turbine blades was found to carry from 1 to 2½ per cent. of copper, while that in the mud drum of the after boiler at the end of the Summer of 1905 showed 3.6 per cent. copper.

The boiler scales showed marked evidence of the water or other boiler additions having carried organic matter, the decomposition of which may have had much to do with increasing the action of the steam on the bronze blades of the turbine.

Tubes of exactly the same composition and manufacture as the above, and similar to them in all respects, have been repeatedly used on vessels fitted with reciprocating engines without showing any such pitting, as for an example, on the yacht *Arrow* these tubes gave excellent service for about eight years without any signs of such corrosion as was found on the *Tarantula* after a few months' service.

From all the facts and information that could be obtained in this case there seems to be no doubt whatever that the copper which caused the pitting on the tubes was taken by the steam from the turbine blades and carried over into the boilers through the condensers and deposited on the tubes.

While of course this is very serious, and, should it have occurred on a new large ship, would have been most costly, yet it seems to be a difficulty which could easily be overcome by some experimenting. It has already been suggested to make the turbine blades of a material the metal of which, if deposited on the boiler tubes, would not have an injurious effect, or to place iron or steel turnings in the hot well, or at some point between the turbines and the boiler, which would take up any deposit of injurious metal before it reached the tubes.

# TRIALS OF THE *LUBECK*.

By R. Veith, Consulting Director in Naval Architecture and Marine Engineering, Vulcan Works, Stettin.

(Translated from "Marine Rundschau" by Commander R. S. Griffin, U. S. Navy, Member.)

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On account of the extended use of turbines for driving dynamos, the German Government entered into contract with the Vulcan Company for the construction of the *Lubeck*, which was to have turbines furnished by the German Parsons Marine Turbine Co. That the results of her trials are only now available is due to the fact that the trials covered much time, involved considerable work and required great elaboration and the sifting of many data.

The contract required that the ship, in a 6-hour trial under forced draft, not exceeding 2½ inches of water, should make a speed not inferior to that of the sister ship *Hamburg* of 10,000 I.H.P., fitted with reciprocating engines and the same boiler installation, and built also by the Vulcan Company; that the coal consumption on the high-power endurance trial and on the coal-consumption trial should not be greater than 1.98 pounds per I.H.P., the I.H.P. to be taken as that developed by the *Hamburg* at the same speed; that on the high-power endurance and the consumption trials the turbines should be run at such a speed as would correspond respectively with about 7,000 and 1,400 I.H.P. for the *Hamburg*; and that the draught of water and other conditions should be as nearly as possible the same for both ships.

The principal dimensions are:

| | |
|---|---|
| Length between perpendiculars, feet, . . | 340.56 |
| Breadth, extreme, feet, . . . . . | 43.31 |
| Draught, mean, feet, . . . . . | 16.40 |
| Displacement, metric tons, . . . . . | 3,217.2 |

The boiler installation consists of ten bent-tube water-tube boilers, without superheaters, and of the type generally used in the German Navy (Schultz-Thornycroft.—ED.), having a collective grate and heating surface of 580 and 29,563 square feet, respectively. The steam pressure is 213 pounds.

The turbines are in two compartments separated by a middle-line bulkhead, and consist of two sets of main turbines and two cruising turbines for ahead motion, and of four backing turbines for astern motion. The arrangement is shown on the accompanying sketch.

Of the main turbine sets, one is in each of the starboard and port engine rooms. Each set consists of a H.P. and a L.P. turbine, each of which operates a screw shaft, thus making four shafts in the ship. Each set is entirely independent of the other, and is used for running at high power. For low and moderate power, the main are coupled up with the cruising turbines, the latter of which consist of a H.P. and a L.P. turbine, the H.P. located in the starboard and the L.P. in the port engine room. They operate the inboard shafts on each side, being on the same shaft as the main L.P. turbines.

The four backing turbines are located one on each shaft, the two inner ones being in the casing of the L.P. main turbines. Originally, the backing turbines were so arranged that both turbines on each side received steam at the same time and had to be operated together. During the trials, however, a stop valve was, for economical reasons, placed in the steam pipe to the inner backing turbine, so that the outer ones could be operated alone.

Originally, each of the four shafts was provided with two three-bladed screws of the following dimensions:

| | |
|---|---|
| Diameter, feet, . . . . . | 4·5 |
| Pitch, feet, . . . . . | 4·5 |
| Surface, projected, square feet, . . . . . | 6.375 |

In addition to these, the Parsons Company provided, for experimental purposes, four other larger screws of the following dimensions:

| | |
|---|---|
| Diameter, feet, | 5.578 |
| Pitch, feet, | 4.918 |
| Surface, projected, square feet, | 9.497 |

All screws were of manganese-bronze.

Three series of tests were made with these two sets of screws:

1st. Trials with eight small ones,

2d. Trials with four large ones,

3d. Trials with four large and four small ones.

Besides the auxiliary machinery, which is the same as in the *Hamburg*, there are in each engine room two lubricating oil pumps, with cooling and filtering connections, for forcing oil through the turbine bearings.

The air pumps are independent Weir "wet" pumps, while in the *Hamburg* they are worked from the engine. Dry-air pumps are not fitted, as in torpedo boat *S–125*. (See page 961, JOURNAL, Vol. XVIII.)

To obtain economy at low and moderate speeds the turbines may be coupled in three ways:

*For low power*—up to about 14 knots—the H.P. and L.P. cruising turbines are coupled up with the H.P. main turbines, from which latter the steam goes to the condenser by way of the L.P. main turbine. (1st Combination.)

*For moderate power*—up to about 18.5 knots—only the L.P. cruising turbine is coupled with the H.P. main turbines. (2d Combination.)

*For maximum power*—both cruising turbines are disconnected and steam is admitted direct to each H.P. main turbine. (3d Combination.)

Reduction of power in each of the arrangements is obtained by throttling. Increased power may be obtained by admitting live steam to the L.P. cruising turbines in the 1st Combination and to the H.P. main turbines in the 2d Combination.

Föttinger torsion meters, which had previously been tested, were mounted on each shaft, in order to measure the power developed.

The coal used was weighed before being put in the bunkers,

and upon completion of the trial that remaining in the bunkers was again weighed in order to get the amount actually used. A check was also kept on the expenditure by means of the usual bucket method.

## TRIALS.

### I. CONTRACT TRIALS.

The contract trials were made with the eight small screws.

(*a*) *Six-hour forced-draft trial.*—The requirements were as noted on page 57, and as the measured-mile trials of the *Hamburg* gave 21.9 knots at 10,000 I.H.P., this was fixed as the contract speed for the *Lubeck*. The mean revolutions for this trial were 662.5, which were equivalent to a speed on the Eckernförde mile of 22.25 knots, or .35 knot more than required.

The turbines and boilers worked without derangement.

(*b*) *Twenty-four-hour coal-consumption trial at cruising speed.*—The measured-mile trial of the *Hamburg* gave 12.4 knots with 1,400 I.H.P., and to reach this speed it was necessary for the *Lubeck* to run at 333.5 revolutions per minute. The coal consumption was 2.204 pounds per I.H.P., or 0.22 more than the contract permitted.

The trial was made with the turbines coupled as in the 1st Combination.

The machinery gave no trouble whatever during this trial.

(*c*) *Twenty-four-hour high-power endurance trial.*—On her endurance trial the *Hamburg* made 20.2 knots with 7,000 I.H.P., and this was the speed fixed for the *Lubeck*, the coal consumption to be the same as that stipulated for the preceding trial. This trial was made with the turbines arranged as in the 2d Combination, with additional steam in both H.P. main turbines. The revolutions required for the speed were 568 per minute, and the average made for the twenty-four hours was 567.3. The coal consumption was slightly in excess of the limit, being 2.13 instead of 1.98 pounds per I.H.P.

(*d*) *Twenty-four hour high-power endurance trial repeated.*—The contractors took exception to the preceding trial, because

a portion of it was run in much shallower water than that on the Eckernförde mile, and, therefore, required a marked increase in power in order to obtain the required number of revolutions. So, the trial was repeated under the following conditions:

"The trial must not be run if the force of the wind exceeds 3. (On coal-consumption trials, the usual limit is 4.)

"Before commencing the trial the fires must be cleaned, and the ship brought to such a draught that the mean draught for the trial shall be as nearly as possible the same as that of the *Hamburg* on her measured-mile trials.

"The mean revolutions will remain as before, 568.

"Should the force of the wind reach 4, the remainder of the trial will not be based on revolutions, but will be run with the same initial pressure in the H.P. main turbines as had been maintained from the commencement of the trial to the time that bad weather set in."

The trial was made on the 8th and 9th of December, 1905, with the stop valve to the L.P. cruising turbine wide open (2d Combination) and some live steam admitted to the H.P. main turbines. For ten hours the force of the wind was 3 to 4 and at times 4 to 5, and during this time the initial pressure in the H.P. main turbines controlled the trial condition.

Turbines and boilers worked satisfactorily. The mean revolutions per minute were 566.5, and the coal consumption was 1.92 pounds, .06 pounds less than the requirement.

Less steam was admitted to the H.P. main turbines than on the former trial, the initial pressure being about 65.4 as against 72.5 pounds. The boiler pressure and the initial pressure in the L.P. cruising turbine were the same on both trials.

The coal per I.H.P. on the trials of the *Hamburg* was 1.91 pounds on the endurance trial at cruising speed, and 1.77 on that at full speed.

### ADDITIONAL TRIALS.

Besides the contract trials, a large number of others was made to determine the influence of different screws and turbine combinations on the speed, coal consumption and maneuvering qualities of the ship.

The trials were divided into four groups, depending upon the propellers and their arrangement, and comprised measured-mile and coal-consumption trials, and determination of the distance the ship will go from full speed ahead to stop under the influence of the backing turbines.

Group I embraces all trials with the original arrangement of propellers—two small ones on each shaft. The highest speed was 22.369 knots, with 672 revolutions and 13,705 shaft horsepower; the slip was 25.11 per cent.

Group II embraces all trials made with the four large screws, which were made with one on each shaft mounted on the after cone. The maximum speed was 22.39 knots with 623 revolutions, 13,029 shaft horsepower, and a slip of 25.97 per cent.

Trials on the mile at Neukrug in deep water, were also made with these screws. The maximum speed there was 23.16 knots with 14,158 shaft horsepower and a slip of 26.5 per cent.

Group III embraces those trials made with two screws on each shaft—a small one forward and a large one aft, and, therefore, with four small and four large screws. The large screws on the outer shafts had to be reduced in diameter about 3.937 inches in order to clear the small screws on the inner shafts in the same athwartship plane. With this arrangement of screws was obtained the greatest speed in relation to power. The speed was 22.562 knots, with 601 revolutions and 13,573 shaft horsepower. The slip was 15.51 per cent. for the forward and 22.67 for the after screws.

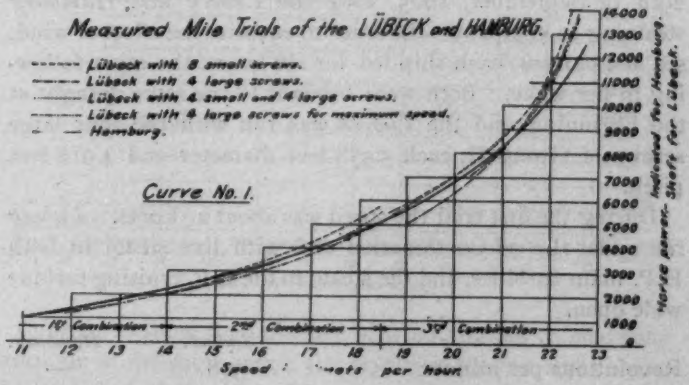
Group IV embraces those trials made with one of the three sets of screws furnished by the Parsons Company. They were built by this company and were expected to give a speed in excess of what had hitherto been obtained, and were of the following dimensions:

| | For outside shaft. | For inside shaft. |
|---|---|---|
| Diameter, feet, . . . . . | 5.25 | 5.75 |
| Pitch, feet, . . . . . | 4.70 | 5.17 |
| Surface, projected, square feet, . | 12.95 | 15.53 |

The screws were placed as in Group II, on the after cone of each shaft.

The maximum speed was 22.551 knots, with 625 revolutions and 13,879 shaft horsepower. The mean slip was 25.79 per cent.

The results of the trials over the Eckernförde mile are given on the accompanying Curve 1.


Measured Mile Trials of the LÜBECK and HAMBURG.
Lübeck with 8 small screws.
Lübeck with 4 large screws.
Lübeck with 4 small and 4 large screws.
Lübeck with 4 large screws for maximum speed.
Hamburg.
Curve No. 1.
1st Combination
2nd Combination
3d Combination
Speed in knots per hour.
Horse power. Indicated for Hamburg. Shaft for Lübeck.

Trials with the large screws on the forward cone of the shaft were out of the question on account of the great cost of alteration in shafts and ship's hull. Measured-mile trials in deep water with propellers other than those of Group II were not made, because it was to be expected that no great difference in speed would be obtained.

The coal-consumption trials were in general of six hours' duration. Before each trial the boilers were thoroughly cleaned, so that it would not be necessary to clean fires during the trial, and the evaporators were not in use. With the eight small screws several trials were made at different speeds and with different turbine combinations. In order to obtain information on the effect of the 3d Combination on coal-consumption some trials were also made with steam to the turbines highly throttled.

Several coal-consumption trials were also made with the four large propellers of Group II.

In the accompanying Curve 2 are given the hourly consumption of coal during the contract coal-consumption trials of the *Lubeck* and *Hamburg*, alongside that of the *Lubeck* on her forced-draft trial and on the unofficial coal-consumption trials.

Special mention should also be made of two coal-consumption trials made on the 25th and 26th and on the 28th and 29th of September, 1905, with the *Lubeck* and *Hamburg* steaming in company. In order to equalize the effect of wind, sea and current, each ship led for six hours, the other following in her wake. Both were brought to the same draught at the beginning, and the *Lubeck* was run with the four large screws of Group II, each 5.578 feet diameter and 4.918 feet pitch.

During the first trial the speed was about 20 knots. *Lubeck* ran under the 2d Combination and with live steam in both H.P. main turbines, and the steam to the L.P. cruising turbine wide open.

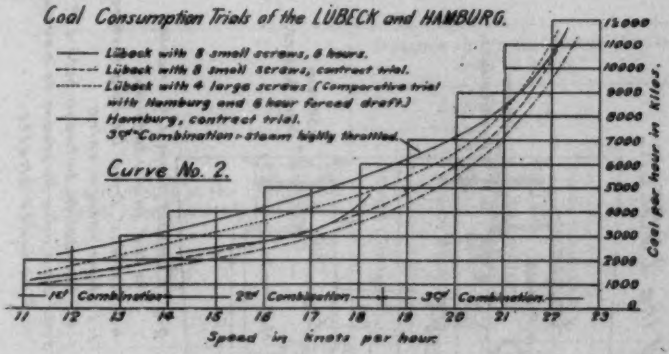
| | *Lubeck.* | *Hamburg.* |
|---|---|---|
| Revolutions per minute, | 508 | — |
| Horsepower, indicated, | — | 7,027 |
| shaft, | 7,662 | — |
| Coal per I.H.P., pounds, | 2.09 | 2.14 |

Force of wind, 3 to 7; state of sea, 3 to 5.

The high consumption of the *Hamburg* compared with that of the *Lubeck* is explained by the fact that the firemen of the former had had very little experience in firing on coal-consumption trials.

The second coal-consumption trial was made at a speed of about 15½ knots. The *Lubeck* operated under the 2d Combination, and developed 3,297 shaft horsepower with 390 revolutions. The initial steam pressure in the L.P. cruising turbine was throttled to about 121 pounds. The I.H.P. of the *Hamburg* was 3,303. The wind was 3 to 5 at the beginning, but died out entirely during the trial, which ended after twenty-three hours on account of a dense fog.

The coal consumption of the *Lubeck*, based on the I.H.P. of the *Hamburg*, was 2.25 pounds, and that of the *Hamburg*, 1.70. The results of these trials of the *Lubeck* and of a six-hour trial under forced draft, with the same screws, are given in Curve 2.


Coal Consumption Trials of the LÜBECK and HAMBURG.
Lübeck with 8 small screws, 6 hours.
Lübeck with 8 small screws, contract trial.
Lübeck with 4 large screws (Comparative trial with Hamburg and 6 hour forced draft.)
Hamburg, contract trial.
3d Combination - steam highly throttled.
Curve No. 2.
Coal per hour in kilos.
1st Combination
2d Combination
3d Combination.
Speed in knots per hour.

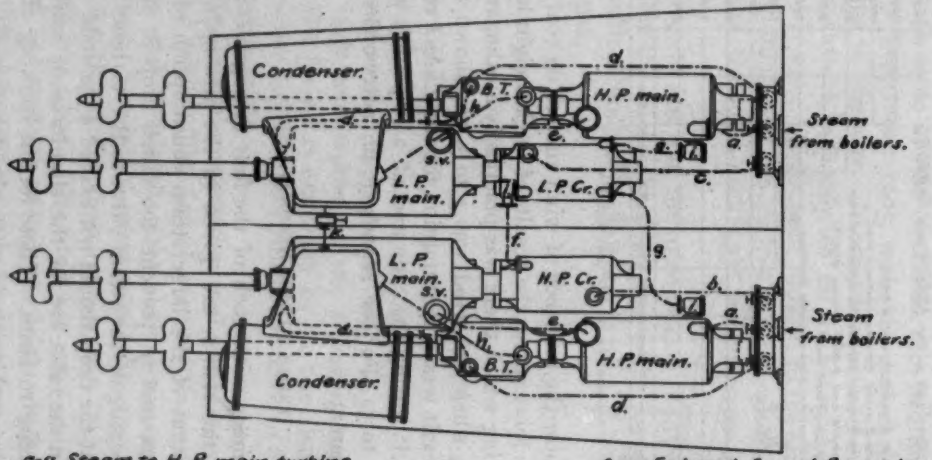
In order to show the influence of wind and sea on coal consumption at the same speed, the results of the last eight hours of the trial, during which there was practically a calm, and of the first fifteen, when the wind was 3 to 5, are shown separately. The result was a consumption for the *Lubeck* of 2.0 pounds per I.H.P. during the calm and of 2.47 pounds when the wind was 3 to 5. For the *Hamburg*, no noteworthy difference was apparent.

### TRIALS TO STOP HEADWAY.

These were made with each of the four arrangements of propellers, and the results are given in the accompanying table. On account of the large steam consumption of the backing turbines, and to prevent too much drop in steam pressure, the opening of the steam valve to the turbines was so regulated that the drop should not exceed 43 pounds.

The figures in the table are for the simultaneous working of all four backing turbines. Those for the working of the two outer backing turbines only were also determined. The

## Steam connections of the Turbine Installation of the LÜBECK.




a-a. Steam to H.P. main turbine.
b. Steam to H.P. cruising turbine.
c. Steam to L.P. cruising turbine.
d-d. Steam to Backing turbines.
e-e. Exhaust from H.P. main to L.P. main turbines.
f. Exhaust from H.P. to L.P. cruising turbines.
g-g. Exhaust from L.P. cruising to H.P. main turbines
h-h. Exhaust from Backing turbine to condenser.
i-i. Non-return valve
K. Connection between both L.P. turbines.
S.V. Stop valve in steam to backing turbines on inner shafts.

difference in time from full speed ahead to dead stop of the ship when backing full speed with the two outer and with the four backing turbines was 23 seconds, and the distance run about 328 feet more. Naturally, the time of stopping cannot be accurately determined on account of the difficulty of telling when the ship is absolutely at rest.

| Number of boilers. | Speed of ship at the time signal "Full speed astern" was given. | Distance run in feet before ship was dead in water. | | | | |
|---|---|---|---|---|---|---|
| | | *Lubeck*. | | | | *Hamburg*. |
| | | Eight small screws. | Four large screws. | Four large and four small screws. | Four large screws (for maximum speed). | |
| 10 | Slow speed, 5 knots..... | 335 | 171 | 164 | 246 | 184 |
| 10 | Half speed, 9 knots..... | 384 | 413 | 361 | 480 | 361 |
| 10 | Moderate speed, 11 knots..... | 755 | 692 | 636 | 700 | 590 |
| 10 | Maximum speed, 22 knots..... | 1,430 | 1,765 | 1,529 | 1,640 | 919 |

## CONCLUSIONS.

The *Hamburg* showed a speed of 22.535 knots on the Eckernförde mile and 23.15 in deep water on the Neukrug mile. The maximum speed of the *Lubeck* is, therefore, practically the same as that of the *Hamburg*. The power developed by the engines of the two vessels are, however, quite different, the turbines of the *Lubeck* having shown in shallow water 13,573 shaft horsepower in Eckernförde Bay and, in deep water, 14,159 shaft horsepower at Neukrug, while the engines of the *Hamburg* under similar conditions developed respectively 11,889 and 11,582 I.H.P. This indicates that the turbine ship required greater power than the one with reciprocating engines. That the *Lubeck* did not get greater speed with this increased power is attributed to the inefficient working of her screws.

The coal consumptiom of the *Lubeck* was higher than that of the *Hamburg*, as will be seen by the following:

| Coal used by both ships referred to the I.H.P. of *Hamburg*. | Cruising speed. | Maximum endurance speed. |
|---|---|---|
| *Lubeck*, . . . . . | 2.20 | 1.92 |
| *Hamburg*, . . . . . | 1.91 | 1.76 |

During the forced-draft trial the coal per hour of the *Lubeck* was 25,117 pounds at 22.265 knots, and that of the *Hamburg* 22,185 at 22.2 knots. The coal for auxiliary purposes is not included. While these figures show a radius of action for the *Hamburg* superior to that of the *Lubeck*, it is to be expected that, with continued use, the valves and pistons of the *Hamburg* will show more leakage, but that the radius of action of the *Lubeck* will, nevertheless, be inferior to that of the *Hamburg*. Thus far, in squadron, the coal consumption of the *Lubeck* has been about 8 per cent. greater.

The distance the *Lubeck* goes from full speed ahead until dead in the water under the influence of her backing turbines is much greater than for the *Hamburg*.

## MISHAPS DURING THE TRIALS.

During the long period covered by the trials the *Lubeck* had only two accidents, and each case was one of serious blade injury. The first time, the rotor and stator blades of the H.P. cruising turbine were broken from the 11th to the 18th row; the second time, the second-stage blades of the L.P. cruising turbines were ground and partly bent. In each case the repairs required about fourteen days.

The clearance between the blades and the casing was then increased, and no more accidents occurred; this increased clearance apparently had no effect upon the economy of the system.

Upon completion of the trials the turbines were examined, and, except for injuries to blades occasioned by wire nails left in the casing after casting, only a few blades were slightly

ground off. The edges of the steam gland collars in the casing of the backing turbines showed knife edges and were partly ground off; one was broken. Those on the shaft of the backing and L.P. main turbines were also ground off.

## WEIGHT AND SPACE REQUIRED.

The combined weight of the turbine and boiler installation of the *Lubeck*, exclusive of the auxiliary machinery, is 609 tons, and the corresponding weight on the *Hamburg*, 652.7 tons. The weight in the *Lubeck* is, therefore, 43.7 tons, or 7 per cent. less than in the *Hamburg*. Disregarding the boilers, which are the same in each ship, the weight of the engine installation of the *Lubeck*, including the necessary auxiliary machinery and appurtenances, is 271 tons, while that of the *Hamburg* is 323 tons, or a reduction in weight of 16 per cent. for the *Lubeck*. The turbine also tends to economy in another direction, in that the protective deck can be worked lower than with a reciprocating engine.

This economy in weight of turbine engines will not be obtained in the turbine ships now under construction, on account of improvements that have been found to be necessary.

The turbine engines of the *Lubeck* are placed in the same athwartship space as the reciprocating engines of the *Hamburg*, but the entire machinery of the *Lubeck* could not, however, be so favorably placed, and it was, therefore, necessary to place the transverse bulkhead two frame spaces further aft than in the *Hamburg*, thus entailing undesirably large spaces.

## FURTHER CONCLUSIONS.

As there are no heavy reciprocating parts on the *Lubeck* as on the sister ship, so there is an absence of the vibration noticeable in the latter. This secures a steady gun platform and a steady compass, by which means improved aiming and steering are obtained. The low position of the turbines and screws secures better protection for them.

So far overhauling has been less necessary than with reciprocating engines, so it is fair to expect a greater readiness for service of ships with turbines.

Turbines are easily maneuvered. The operation is simpler than with reciprocating engines because it is merely the opening and closing of a valve, which does away with a reversing gear. There is an absence of annoyance caused by water in the cylinders when maneuvering, because the water is broken up into very small particles.

The small attention necessary during the working of the turbines, the little overhauling and cleaning while idle, which advantages (on account of the steam being free from oil) extend to the boilers, condensers, feed-water heaters, etc., save the personnel. Injury to attendants is unknown with turbines.

On account of the high temperature and excessive moisture in the engine rooms of the *Lubeck*, improvement in these conditions may be looked for. A reduction in personnel was not attempted. Whether improvements in turbines will bring about such a reduction must be left to further experience.

## CONCLUSION.

The trials of the *Lubeck* have furnished most valuable information, but they have not been entirely conclusive, because the ship had to take her place in squadron. She is the first of our larger ships to have turbines. If, in competition with the highly developed reciprocating engine, it has shown a few defects, this beginning may, taken all in all, be considered a success.

As an evidence of its preference for turbines, and for further investigation of the turbine question, the German Admiralty has recently contracted for turbines for the small cruisers *Ersatz Wacht* and *Ersatz Komet*, notwithstanding the fact that they had to pay a much higher price for turbines than for reciprocating engines. The subsequent cost of maintenance will more than balance this first cost. Parsons turbines have

been decided upon for both ships, because other turbines for large ship installations are still in the experimental stage. Whether the Parsons will be the only turbine used in our Navy remains to be seen; others may, in short time, reach such a stage of development as to be able to compete with it.

# CHARACTERISTICS IN DESIGN AND ARRANGEMENT OF MARINE TURBINES AND PROPELLERS.

By Ernest N. Janson, Member.

## II.—CURTIS SYSTEM.

Apart from the turbines and their action, machinery installations with Curtis steam turbines for propelling purposes differ from Parsons principally in the division of the total power transmitted to the propellers. As now constructed turbine arrangements of Parsons type consist generally of three units, often of four, but rarely of two, this latter arrangement having been used in only one instance, so far as known, namely, in that of the *Narcissus*, a steam yacht of small power. With Curtis type the prevailing practice comprises the regular twin-screw system, with two turbines and two shafts. Where the power needed is small, as in steam launches, a single shaft driven by one turbine is most suitable. Arrangements of three or four shafts with an equal number of turbines have not as yet been proposed, the reason of which may be attributed to certain inherent features in this type of turbine, rendering a twin arrangement more desirable. Enhanced cost and excess in weight as well as space over the present system would perhaps also follow. Each turbine being entirely self-contained, or, in other words, having within a single casing the parts corresponding to the high-pressure and low-pressure turbines as well as reversing turbines of Parsons' system, would, with a multiple shaft arrangement, properly require independent condensers, air pumps and circulating pumps for each unit, and, therefore, considerably add to the number of auxiliaries. In very large installations, however, such as in the *Mauretania* and *Lusitania*, where the auxiliary units, on

CURTIS MARINE TURBINE U. S. S. "SALEM."
8,600 B.H.P.

4-CYL. TRIPLE-EX. MARINE ENGINE U. S. S. "VERMONT."
8,250 I.H.P.

account of the extraordinary power, in any event have to be divided up, it is not probable any great difference between the two systems as to auxiliaries would appear, other things being equal.

Principal exterior dimensions of the turbine are primarily influenced by the speed of revolutions partly determined by the propeller, therefore indirectly by horsepower and speed of ship. Initial steam pressure and the pressure at the condenser do, in a measure, determine the length, but are of greater moment with respect to internal dimensions.

Illustrations in half tone facing page 72 show comparatively the space occupied by an engine and a Curtis turbine. The following dimensions will explain:

TURBINE.

*120 inches, 7-stage, 350 R.P.M.*

| | |
|---|---|
| Length over all, casing | 16 feet 2½ inches. |
| Width over all, casing | 13 feet 6 inches. |
| Height over all | 12 feet 6 inches. |
| C to C, main bearings | 18 feet 6 inches. |
| Weight | 102 tons. |

ENGINE.

*32½ inches × 53 inches × 61 inches × 61 inches × 48-inch stroke. 120 R.P.M.*

| | |
|---|---|
| Length over all, cylinders | 33 feet 6½ inches. |
| Width over all, cylinders | 11 feet 3 inches. |
| Height | 21 feet 9 inches. |
| C to C, end bearings | 25 feet 3½ inches. |
| Weight | 153 tons. |

The usual pressure employed at the turbine inlet is about 265 pounds absolute, but may be almost any reasonable quantity within practicable limits of boiler and steam-pipe constructions. It must be remembered that with this type of turbine the pressures are confined initially within small nozzles and that the casing receives the steam after it has been expanded. The vacuum should be as high as possible, 28 to 29 inches being aimed at, and the former, at least, is readily obtained. In this connection it is interesting to point out that a vacuum as high as 28 inches is obtained in marine turbine arrange-

ments with an air-pump capacity less than that required for reciprocating engines running with 27 inches, and this without additional apparatus either in form of "augmentors" or dry-vacuum pumps. The reason is plainly to be found in the steam-packed glands in the turbine, therefore fewer air leaks. Condensers of large surface, together with a considerable amount of cooling water, are invariably required to adequately condense the steam. As an instance may be cited a large ocean-going turbine steamer now running equipped with both dry and wet-air pumps, maintaining a steady vacuum of 28¼ inches with the latter alone in operation, the dry pump having no function except its presence. The condensers, however, are large, having about 1.6 square feet of cooling surface per equivalent I.H.P.

The importance of simultaneously considering the design of propeller and turbine having been discussed in a previous article, it is now necessary only to transform the data there given to conform with the new condition, namely, that of dividing the power on two units instead of, as then, on three. A few modifications have been introduced for certain constants used to agree with more recent observations.

*Preliminary design.*—In making first approximations of revolutions of the turbine rotor we will base assumptions of vane speeds on knowledge gained in experiments carried out by those interested in the Curtis marine turbine. Suitable vane speeds vary between 175 and 190 feet per second with a turbine working within a pressure range of about 265 pounds absolute and with steam speeds from 2,000 feet per second down to 1,200 feet as obtained by expansion in various sets of nozzles arranged in a sufficient number of stages.

For reasons of more ready applicability it seems convenient to refer the problem to some specific case. Having this in view we will presume the following:

Type of ship, torpedo-boat destroyer.

Speed of ship, 33 knots per hour.

Effective horsepower required at this speed, 8,000, found by tank experiments on models.

FINISHED MARINE TURBINES. 8,000 AND 250 H.P., RESPECTIVELY.

Twin screws.

Curtis turbine, marine type.

Moreover, that the weight of engines for this class of machinery must not exceed 15 pounds per horsepower. Based on weights of turbines built, we find the mean vane diameter should be about 83 inches. Then, using an adopted mean vane speed of 183 feet per second, we get for revolutions of the rotor,

$$\text{R.P.M.} = \frac{60 \times 183}{\frac{83}{12} \times \pi} = 508,$$

which we will use to determine the dimensions of the propeller.

## THE PROPELLER.

The great advantage of rotor speeds as high as condition will permit has been pointed out, and are a necessity both for efficiency in working and to minimize dimensions of the turbine. The propellers being driven by direct connection to the turbine rotor must revolve at the same high speed. The speed of revolutions and the diameters needed for certain powers bring the tip speed in many instances as high as 13,000 to 14,000 feet per minute, but although the efficiency of the propeller rapidly diminishes at such speeds, it has been found that the combined efficiency becomes greater and that the increased turbine efficiency more than counterbalances the decrease in propeller efficiency. A limit of 12,400 feet per minute for tip speed will be set for the example to follow.

Although many recent investigations and experiments have thrown light, as to design of propellers, on certain features as desirable and others as detrimental, the blade theory, propounded by Froude and worked out by Taylor for practical application (see Resistance of Ship and Screw Propellers, by D. W. Taylor), may be used with advantage in calculating the screw. This is especially true for a case as the one in hand dealing with conditions entirely different from those existent in engine work, and for which not a great deal of actual data are to be found.

Dimensions of propellers are influenced directly by—

1. Speed ($K$) of ship in knots per hour.
2. The effective horsepower ($E.H.P.$) needed for propulsion.
3. Real slip ($S$).
4. Diameter ratio $\left(\frac{D}{P}\right)$ which is the relation of diameter and pitch.
5. Number ($N$) of blades.
6. Pressure ($Ps$) per unit of projected blade surface.

Real slip of propeller $S = S_1\ (1-w) + w$,

in which

$S_1$ = apparent slip.

$w$ = wake.

Pitch ($P$) and revolutions ($R$) of propeller must conform to assumed slip and speed, and the diameter ratio must be such as to permit the propeller to be run at the stipulated turbine revolutions.

The effective horsepower delivered by a propeller per second is obtained from

$$E.H.P. = \frac{1}{550\times 60^3} P^3\times R^3\times D^3\times N(I-S)(aSA-fB). \quad (1)$$

The total horsepower absorbed by a propeller per second from

$$H.P. = \frac{1}{550\times 60^3} P^3\times R^3\times D^3\times N\,(aSA-fC), \quad (2)$$

Dividing (1) by (2) we get the propeller efficiency ($e$),

$$e = (1-S)\,\frac{aSA-fB}{aSA+fC}.$$

Applied to our example we get:

$E.H.P.$ = 8,000 to be equally divided among two shafts;

$R$ = 508, determined by minimum speed of revolution per minute of turbine rotor with reference to weight and space, and assumed vane and steam speeds;

Speed of ship = 33 knots per hour;

Real slip = 8.5 per cent. from an assumed apparent slip = 4 per cent., and wake = 4.5 per cent;

Effective thrust, per screw,

$$T = \frac{E.H.P.}{K} \times 325.8 = \frac{\frac{1}{2} \times 8{,}000 \times 325.8}{33} = 40{,}000 \text{ pounds.}$$

Helicoidal area = (Disc — Hub) × disc area ratio.

The hub is approximated from shaft, easily obtained when power and revolutions are known.

Assume disc area ratio = .5 = $M$;

Tip speed = 12,400 feet per minute = $T_s$;

From drawing area of hub = 2.18 square feet = $H$.

Helicoidal area either by trial or some such simple formulae as this: $\left\{ \frac{I}{12.5} \left( \frac{T_s}{R} \right)^2 - H \right\} \times M = \left( \frac{12{,}400^2}{12.5 \times 508^2} - 2.18 \right) \times .5$

$= (47.7 - 2.18) \times .5 = 22.8$ square feet.

The disc being 47.7 square feet gives a diameter of 7 feet 9½ inches. Having found the diameter corresponding to tip speed stipulated, and the area ratio to give certain allowable pressures, it remains to determine pitch for the assumed slip and to verify diameter for horsepower to be transmitted. We have $P \times R = \frac{101.33 \times 33}{1 - .04} = 3{,}483$, and, therefore, pitch ($P$) $= \frac{3{,}483}{508} = 6.85$ feet.

An approximate propeller is now laid down, Figure 1, and the blades sketched in, the area of which should be about 23 square feet. We will choose a three-bladed screw as most suitable.

The blade as drawn shows a maximum width ratio $\left( \frac{I}{D} \right)$ of about .35. From the approximately-found diameter and pitch we get

$$\text{Diameter ratio} = \frac{7.8}{6.85} = 1.14.$$

The blade characteristics $A$, $B$ and $C$ may now be found for this diameter ratio, and corresponding to the dimensions and contour actually existing in the blade drawn, by integrating functions involving diameter ratio, slip and width ratio.

(See Naval Architecture by Peabody, in which the procedure has been carried out for the "standard" blades. Any other blade must, of course, be treated separately.)

This being done, we get

$A = .878$, $B = 1.186$, and $C = 6.22$, which when reduced to actual width ratio (.35) gives

$A = .876 \times .35 = .3067$;

$B = 1.186 \times .35 = .415$;

$C = 6.22 \times .35 = 2.18$.

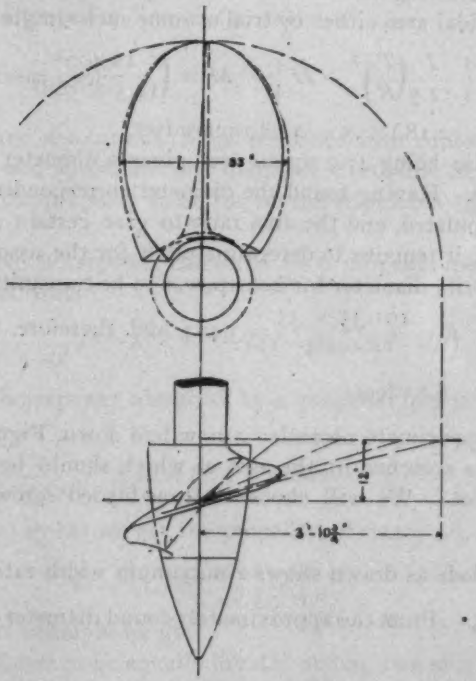


Figure 1.

With respect to other quantities we have for the thrust factor

$a = 3.3 - .4\frac{D}{P} = 2.84$, and

$f$, co-efficient of friction, $= .016$.

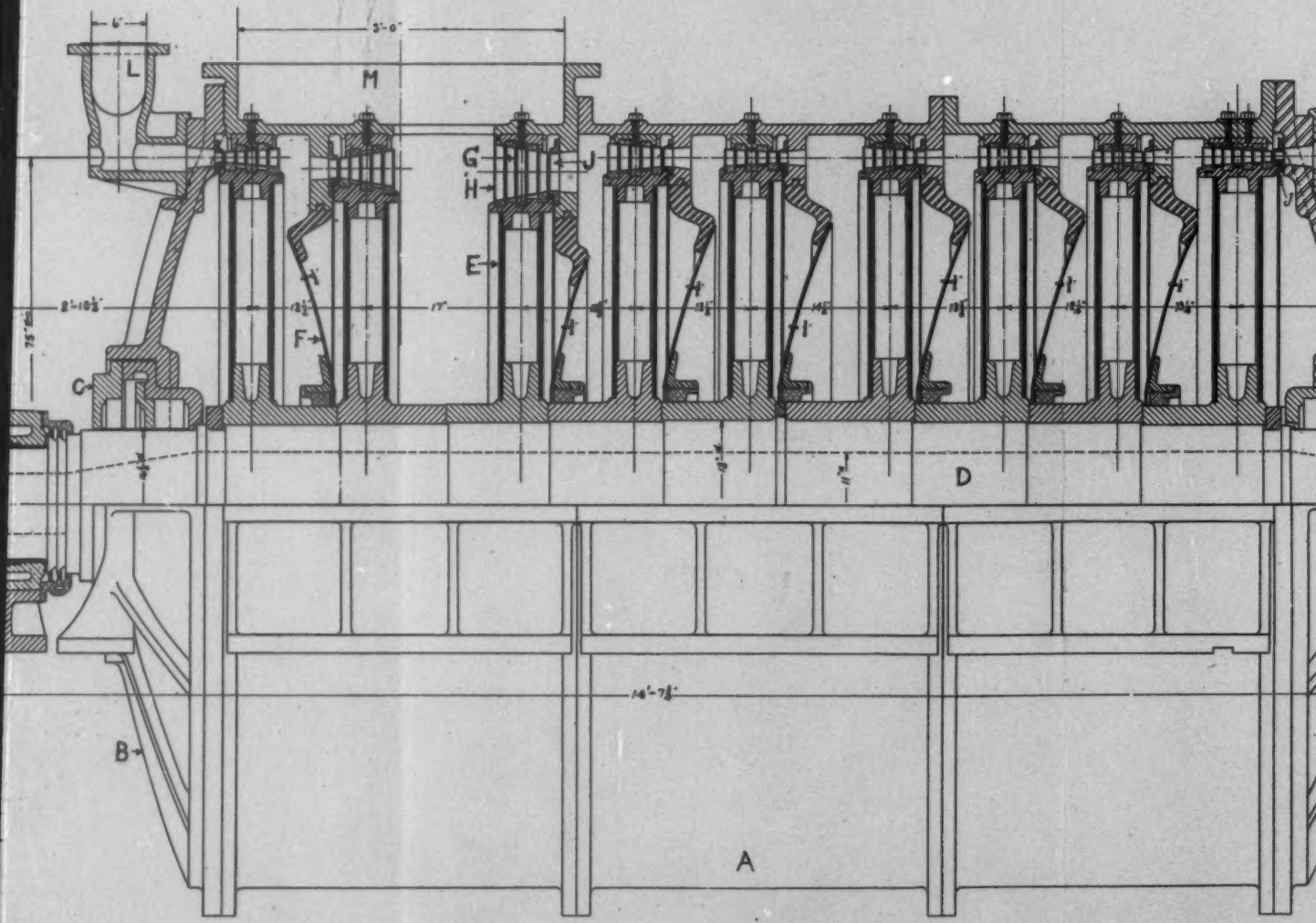
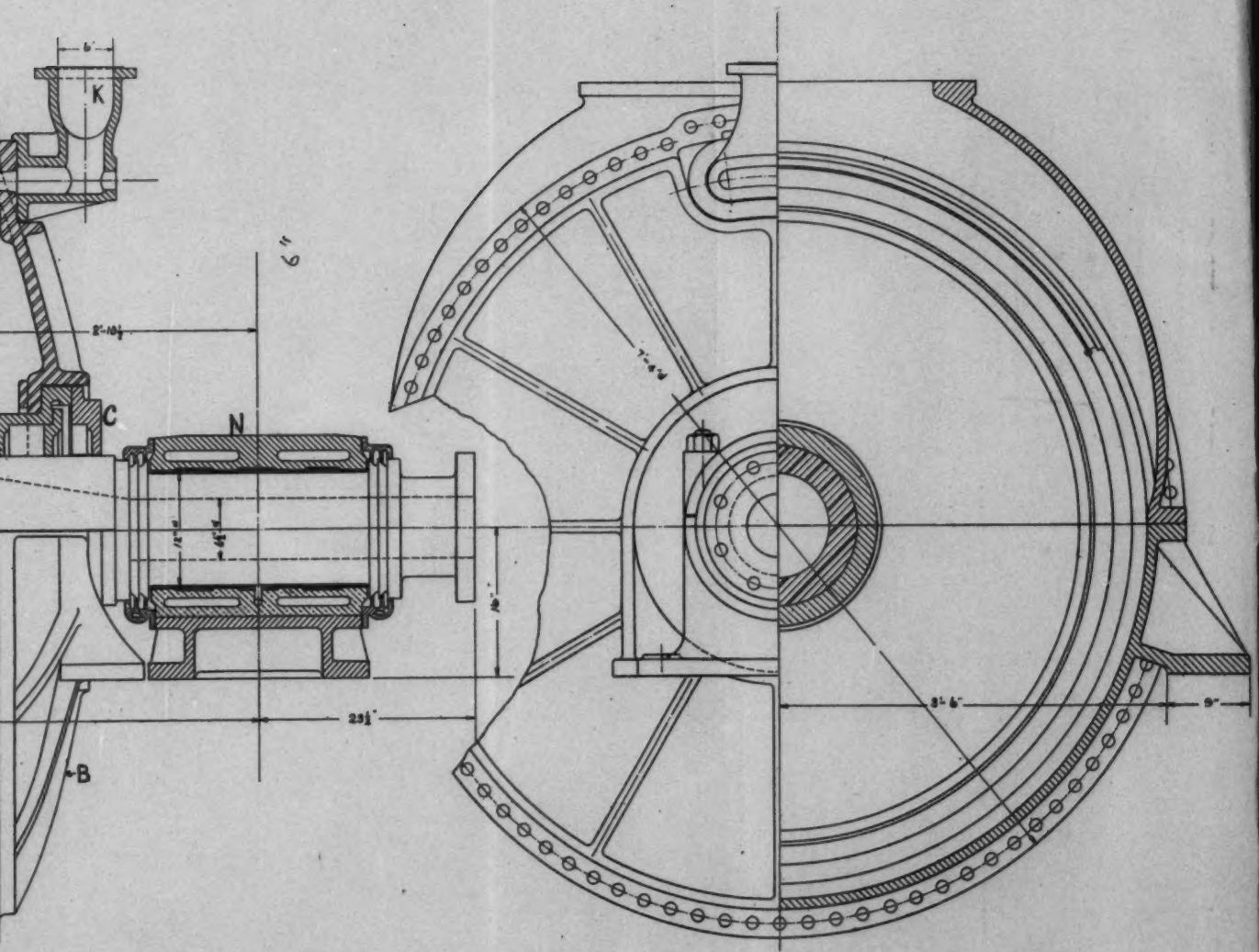
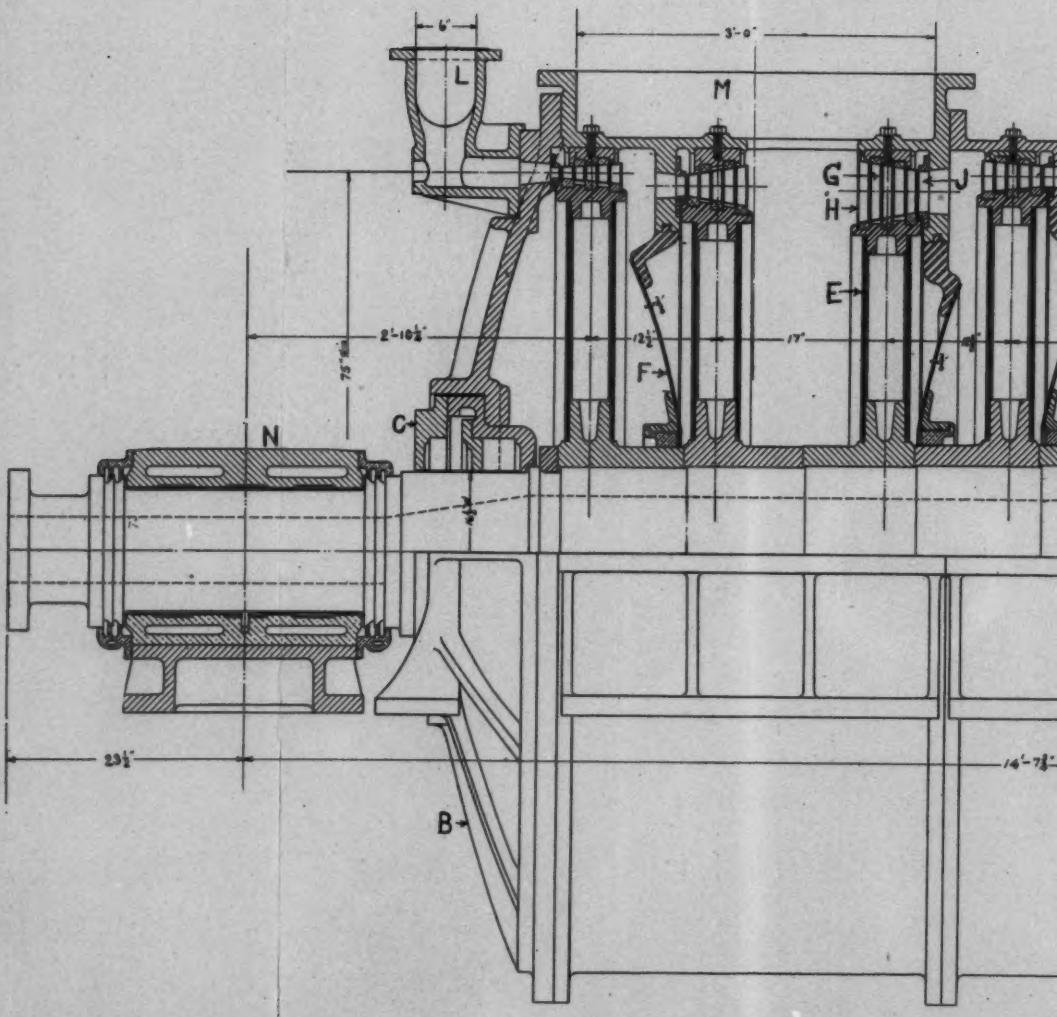



**Figure 2.** — 75-INCH CURTIS MARINE TURBINE. — 2,000




000 HORSEPOWER.


6"
3'-0"
L
M
G
H
J
E
H'
12½"
17"
4"
F
H'
2'-10½"
C
N
23½"
14'-7½"
B

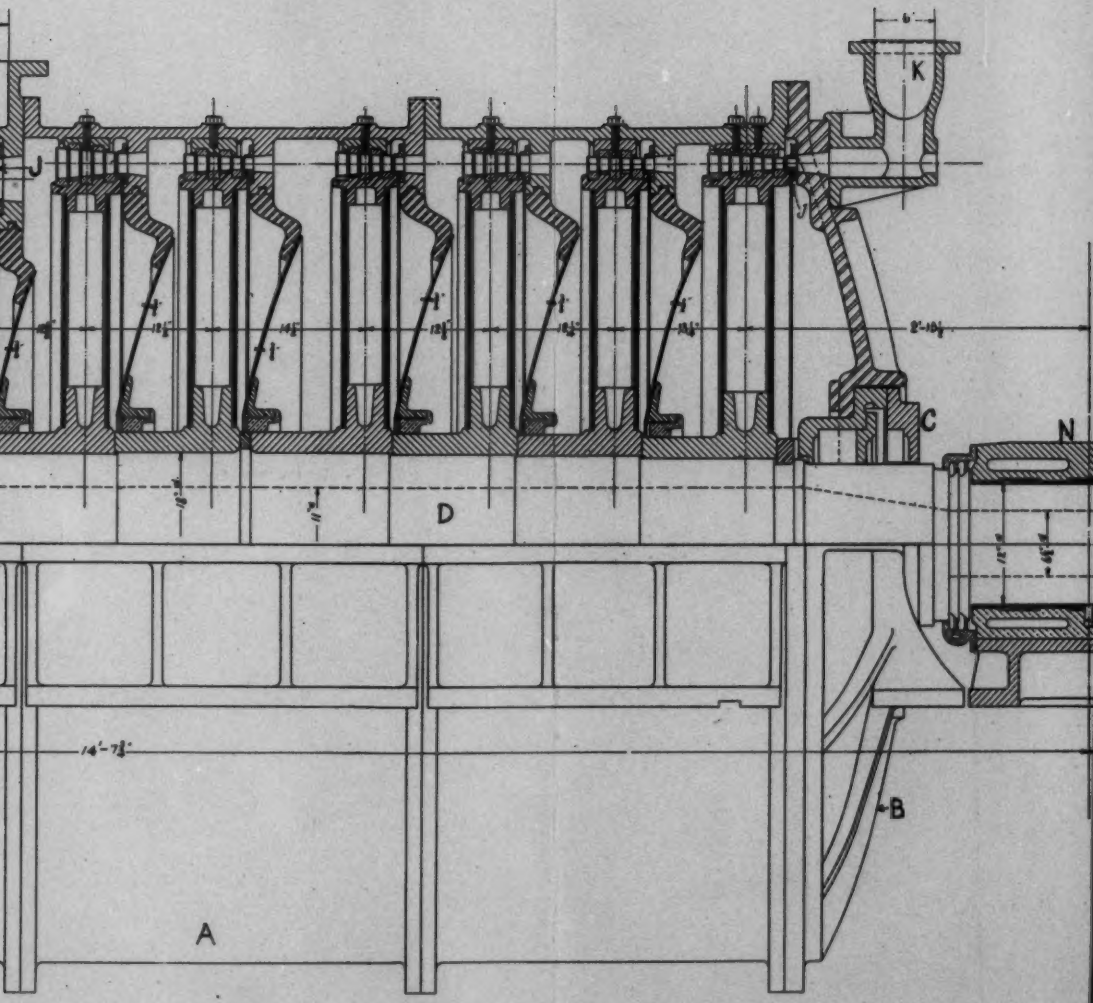



**Figure 2.** — 75-INCH CURTIS MARINE TURBINE. — 2,000 HORSEPOWER.

$N = 3$ by choosing a three-bladed screw, and

$N\ (1-S)\ (aSA-fB) =$

$3\ (1-.085)\ (2.84 \times .085 \times .3067 - .016 \times .415) = .185.$

$$D = \sqrt{\frac{4{,}000 \times 550 \times 60^3}{3483^3 \times .185}} = \sqrt{60.7} = 7.8 \text{ feet.}$$

Efficiency $e = (1 - .085)\ \dfrac{.0674}{.074 + .03488} = 57$ per cent.

The projected area from drawing = 19.7 square feet, and pressure per square inch of projected surface $P_s = \dfrac{40{,}000}{19.7 \times 144}$ = 14 pounds.

Total brake horsepower at turbine end of shafting = $\dfrac{1.04 \times 4{,}000}{.57 \times .98} = 7{,}460$, based on 57 per cent. propeller efficiency and .98 per cent. line-shaft efficiency, and 4 per cent. increase due to thrust deduction and wake.

The indicated horsepower of a reciprocating engine to deliver foregoing effective horsepower would be $\dfrac{7{,}460}{.92} = 8{,}108$, based on 92 per cent. mechanical efficiency.

## THE TURBINE.

*Description.*—The Curtis marine turbine was developed from the stationary type of turbine and contains all the essential features of that type. The first marine turbine built of Curtis type was for the yacht *Revolution*, of about 2,000 horsepower distributed on two shafts, each with one propeller. Each turbine had then only two ahead stages and one reversing stage arranged on the outer rim of the low-pressure rotor. The present marine turbine consists of seven ahead stages and two for backing, the rotors for each being all independently attached on the spindle or main shaft. The general construction as well as principal details may be understood by the description following and by reference to Figure 2, representing a marine turbine of about 3,500 B.H.P. running at 475 R.P.M.

The term "stage" implies the space within two diaphragms,

containing rotating and stationary vanes and a set of nozzles. The casing (A), made of cast iron, is built up of several sections of semi cylinders bolted together, the upper half being secured to the lower by longitudinal flanges. Dished heads (B), in one casting, are bolted to the ends of the cylinder and contain the shaft stuffing boxes (C). The packing in these stuffing boxes consists of double sectional rings of pure carbon, the space between being steam packed. The main shaft (D) is of wrought-steel and hollow, necessarily of a large diameter to secure rigidity. The rotors (E) are built up of cast hubs, forged rims and boiler-plate sides rivetted and screwed. The diaphragms (F) consist of cast or dished plates rivetted to steel rings, the inner of which has a composition boss within which the rotor hub revolves, the outer one a dovetailed extension fitting a groove in the casing, which holds each diaphragm in position. They are made in one piece, as there exists no need for removal; the upper casing, however, can be lifted up by disconnecting the flanges. The blading for each stage is made up of stationary vanes (G) and rotating vanes (H), the former in grooves of sectional attachments screwed to the inside of the casing, the latter in grooves of the rotor rim. The vanes are not, as in most other turbines, inserted and fastened independently or individually, but are made up in blade segments from 10 to 12 inches long, consisting of a foundation ring, the vanes and a shroud band all cast together. When the vanes are short, they may be milled out of the solid, but are usually built up as described, the vane itself being extruded from blooms of a special composition. The bodies (I), containing the nozzles, are secured to the casing at each stage, and consist of a casting with apertures separated by properly formed nickel-steel plates cast in the body. The steam inlet for the ahead stage is at (K) and for the backing stage at (L), the exhaust nozzle for both being at (M). Of the nozzles those in the first stage, both ahead and backing, are expanding, all the others are parallel. The rotor shaft rests in the bearings (N) and revolves in oil under pressure. Steam leakage outward in the stuffing boxes

A B C D

BLADE SEGMENT.

A Blades in core ready for casting.
B Blade.
C Segment, rough casting.
D Segment, finished casting.

(or air leakage inwards) is brought to a minimum by connecting the annular spaces, between the carbon packing rings of the gland, to some intermediary stage where the pressure is only slightly above the atmosphere.

The steam velocities through the nozzles in the various stages are so arranged as to allot one-quarter of the total energy in the steam to the first stage and one-eighth to each of the other six. This is done to obviate an undesirably high shell pressure in the first stage, in which otherwise both the bursting and distorting stress would act detrimentally on the large shell area. Losses on account of the high frictional resistance, which occurs when a fast-rotating disc revolves in dense steam, are also, thereby, materially lessened. To illustrate the working conditions of a turbine of this kind the following data are given, which are supposed to answer to a turbine developing about 1,200 horsepower. The pressures put down in the third column, which are the stage pressures, convey clearly the situation. For any other turbine of different power, but working under similar conditions, the corresponding pressures will, of course, be nearly the same.

**Table I.**

| Stage. | Absolute inlet pressure, pounds per square inch. | Absolute shell pressure, pounds per square inch. | Throat pressure in nozzle, pounds per square inch. | Square inch of throat required, one nozzle. | Absolute nozzle end pressure in lbs. per square inch. | Square inches of nozzle end required, one nozzle. |
|---|---|---|---|---|---|---|
| 1 | 265.0 | 79.0 | 152.9 | 1.339 | 95.7 | 1.5048 |
| 2 | 79.0 | 41.7 | 45.58 | 4.24 | 45.58 | 4.24 |
| 3 | 41.7 | 21.2 | 24.0 | 7.8 | 24.0 | 7.8 |
| 4 | 21.2 | 10.4 | 12.23 | 14.84 | 12.23 | 14.84 |
| 5 | 10.4 | 4.9 | 6.0 | 29.25 | 6.0 | 29.25 |
| 6 | 4.9 | 2.2 | 2.83 | 60.66 | 2.83 | 60.66 |
| 7 | 2.2 | 1.0 | 1.27 | 135.0 | 1.27 | 135.0 |

The first-stage nozzles have each a separately-operated disc valve for shutting off or opening to steam. All of the other stages are furnished with slide valves by means of which a certain number of their nozzles can be closed.

The steam flow through the turbine may accordingly be regulated to correspond with an amount of steam required for any desired horsepower, and the function of these valves thus bear the same relation to an economical variation of the power as do cruising turbines with Parsons' system. Regulating valves as described are necessary on turbines for naval ships cruising the greater part of their time at low power. For ordinary service the regulation may be accomplished by the throttle, and those valves are, therefore, limited on mercantile turbines.

Besides the independently-operated stage valves pressure gauges are located on the shell to ascertain the pressure within each stage. A drain valve connects each stage in such a way as to lead the drain from a preceding stage direct into the next following and successively into the exhaust cavity, at which point a connection is made with the condenser.

*Arrangement.*—Machinery installations with Curtis turbine for propelling purposes of large power, as mentioned before, are arranged for two shafts in the ordinary way, see Figure 3. The disposition of the auxiliary machinery is, in general, also similar to that of arrangements with reciprocating engines. Two separate steam inlets are, however, required, one for ahead the other for backing, the pipes of which, with their throttle valves, connect to the nozzle bowls of the first stage. As there exists only slight end thrust on the rotor from uneven steam balance on the vanes within the cylinder, nearly all of the propeller thrust must be provided for in the usual manner in form of a thrust block, which is placed either forward or aft. The vane clearances being comparatively liberal all around, and there being an absence of dummy pistons with their close settings, renders micrometer adjustments in the thrust block entirely unnecessary. Gauges are, however, provided at the front and back of the turbine to enable the precise location of the rotor, with reference to the stationary parts, being determined.

*Design.*—The real difficulty when starting out in designing a steam turbine centers around the ability to determine the

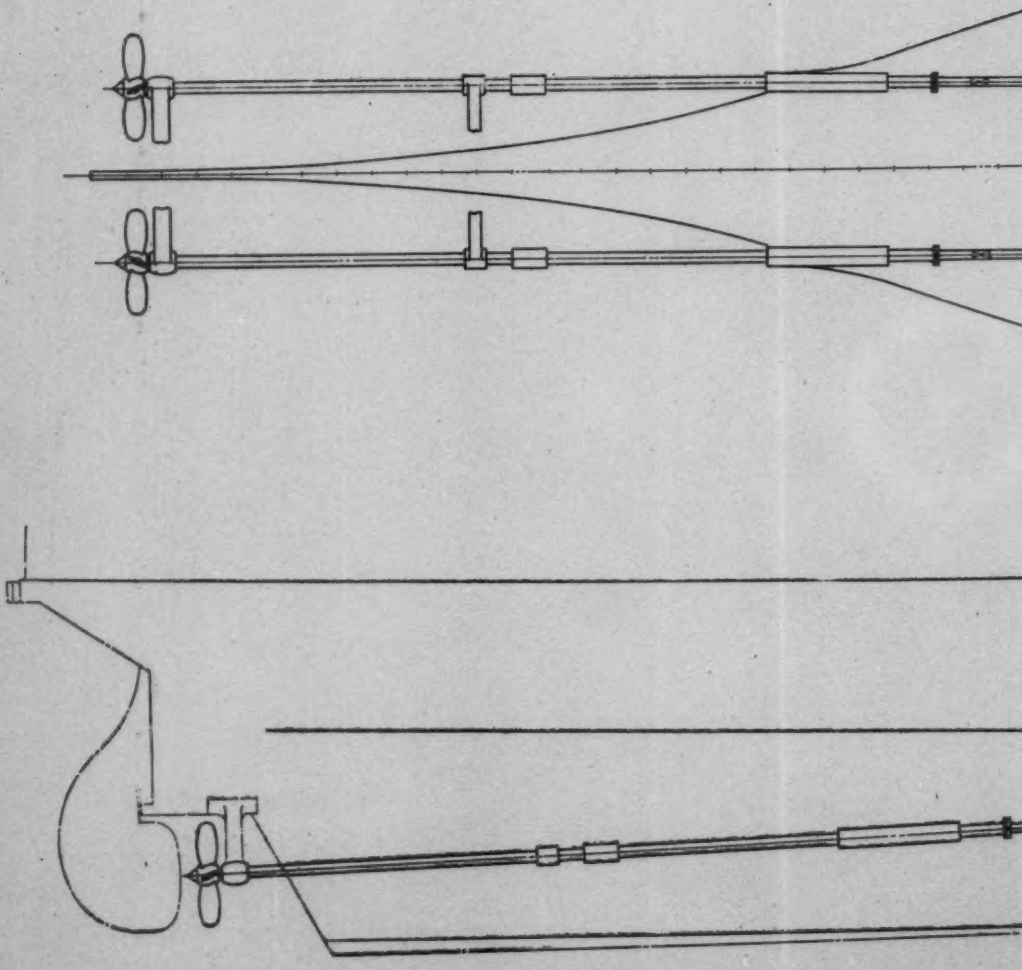
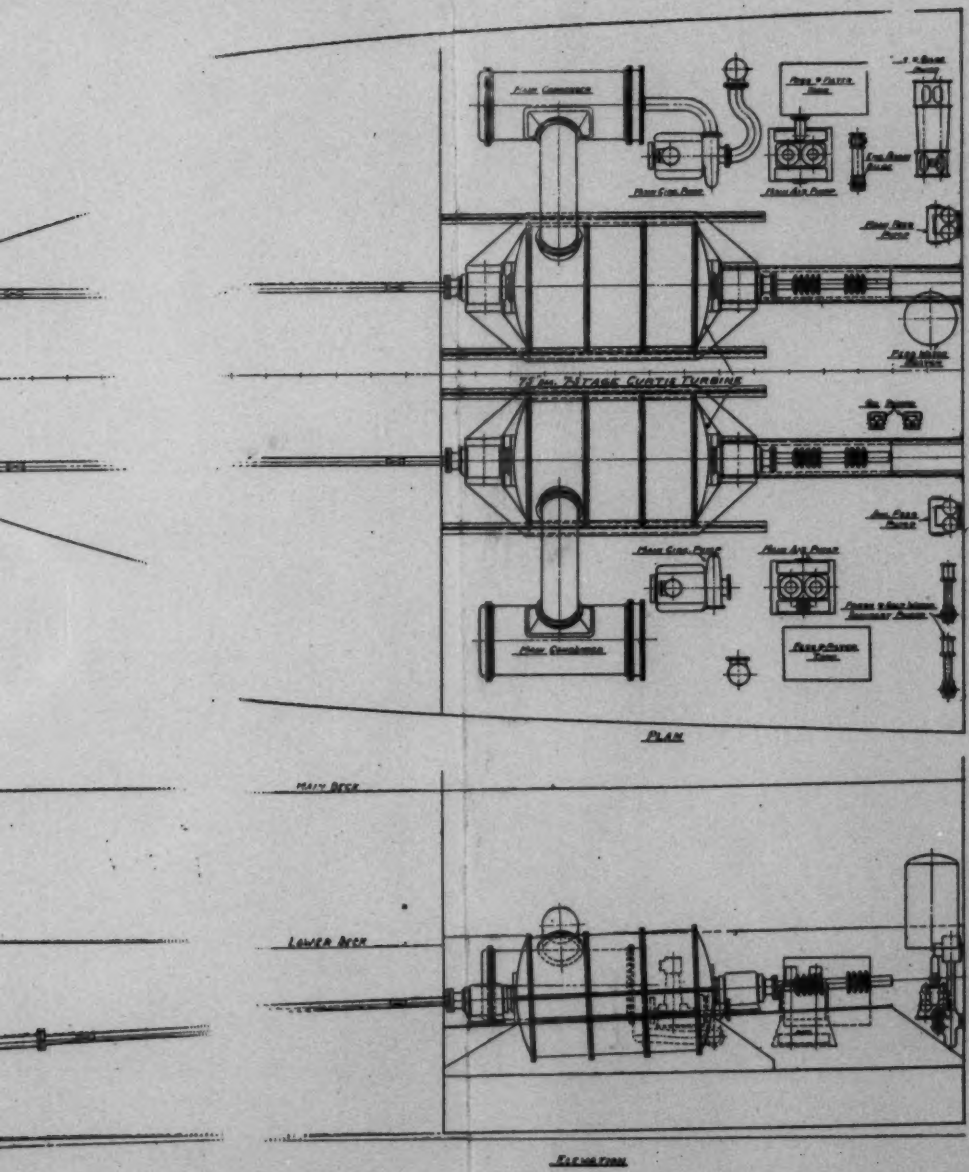


Figure 3.—Machinery Arrangement, 75-




T, 75-INCH CURTIS MARINE TURBINES.

efficiency, or, in other words, to closely approximate the pounds of steam needed per horsepower for given conditions of pressure at entrance and exhaust and defined stipulations as to the quality of the steam. To do this in any turbine, and especially in turbines of the impulse type, like Curtis or DeLaval, it is necessary to base one's assumptions on data secured in tests or by actual experiments. Such tests have been performed most carefully with the present seven-stage Curtis marine type. An average result of such tests justifies us to assume a steam consumption of 14 pounds per brake horsepower, using dry saturated steam at an initial pressure of 265 pounds absolute and a vacuum of 28 inches, the rotor vane speed at the same time to be approximately between 180 and 190 feet per second and the allotment of power as previously stated among the seven stages.

With the use of superheated steam, for which this type of turbine is particularly well adapted, the consumption will undoubtedly be considerably lowered, down to 13 pounds or better, which has been amply verified in various stationary turbine plants.

The total available heat per pound in steam expanding adiabatically between 265 pounds and 1 pound absolute determined by the formulae $H_1 - H_2 = Q_1 - Q_2 + H_v - T_2(E_{f1} + E_v - E_{f2})$ we find =

$380.2 - 70.0 + 825.6 - 563(.5728 + .952 - .1329) = 352.2$ B.T.U.

(See J. A. S. N. E. of August, 1906.)

If all of the heat contained in the steam could be converted into work on the shaft the consumption of the ideal turbine would be $\frac{1{,}980{,}000}{352.2 \times 778} = 7.21$ pounds per horsepower-hour.

The actual turbine, on the basis of 14.0 pounds steam per horsepower-hour, will accordingly give an efficiency $= \frac{7.21}{14.0}$ $= 51.52$ per cent.

The losses in an impulse turbine may be attributed to the following causes:

1. Steam friction in nozzles.

2. Steam friction in vanes.

3. Steam shock on the vanes caused by deviation in the relative entrance velocities and by starting the quiescent steam between the vanes when passing nozzles.

4. Resistance to the revolving surfaces in steam of more or less density.

5. Radiation of heat from the cylinder, spreading and leakage of steam between vanes, nozzles and shaft bushings.

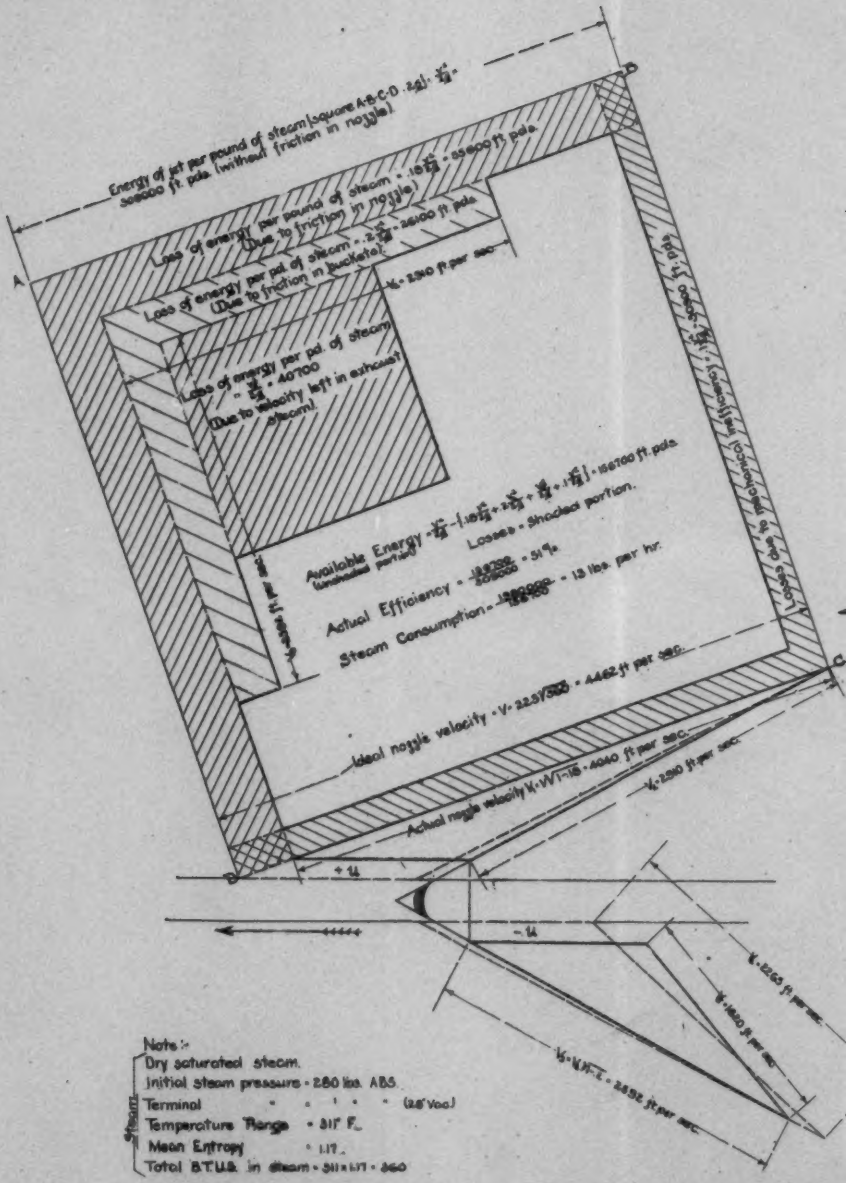
6. Loss of energy due to the exit velocity.

7. Mechanical losses, such as friction of journals and stuffing boxes.

*The nozzle.*—Weight, space and propeller speed renders it necessary, in marine turbine installations, to limit the rotor diameter as well as its speed of revolutions, and incidentally to use low steam speeds. These are obtained by arranging the turbine for a comparatively large number of "expansions" or stages and by using appropriate types of nozzles.

The general principles of steam expansion and the velocity attained by the jet in different nozzles has been written up extensively in various treatises and does not come within the scope of this paper. Suffice it to say, therefore, that the jet velocity depends essentially upon the "ratio of expansion," or on the proportions observed in the areas of throat and outlet end of the nozzle and upon the initial and terminal pressure at the orifice and outlet. Moreover, that a definite relation always exists between the initial pressure and that of the throat, when the orifice is well rounded. Thus if $P$ signifies the initial pressure, the throat pressure will be $.577\ P$ if the outlet pressure is equal to this or any other pressure below $.577\ P$ down to a perfect vacuum. This occurs in either a parallel or an expanding nozzle.

The diagram appended, Figure 4, of a DeLaval conical divergent or expanding nozzle, calculated to expand steam from 280 pounds absolute to 1 pound absolute, illustrates the relation of pressures, cross-sectional areas and velocities at different parts of the nozzle. The energy resulting from


Energy of jet per pound of steam (square A-B-C-D) 224 - 1/2 -
568000 ft. pds. (without friction in nozzle)
Loss of energy per pound of steam = 18 1/2 = 55800 ft. pds.
(Due to friction in nozzle)
Loss of energy per pd. of steam = 2 1/2 = 26100 ft. pds.
(Due to friction in buckets)
V = 2360 ft per sec.
Loss of energy per pd. of steam
= 1/2 = 40700
(Due to velocity left in exhaust steam)
Loss of energy per pd. of steam due to velocity left in exhaust steam
Available Energy = 1/2 - (18 1/2 + 2 1/2 + 1/2 + 1 1/2) = 156700 ft. pds.
Losses - Shocked portion.
Actual Efficiency = 156700/568000 = 31%
Steam Consumption = 1980000/156700 = 13 lbs. per hr.
Ideal nozzle velocity = V = 223√2gh = 4462 ft per sec.
Actual nozzle velocity V1 = V√.715 = 4040 ft per sec.
V1 = 2360 ft per sec.
+ u
- u
V = 1255 ft per sec.
V = 1820 ft per sec.
V1 = V1 - 2 = 2692 ft per sec.

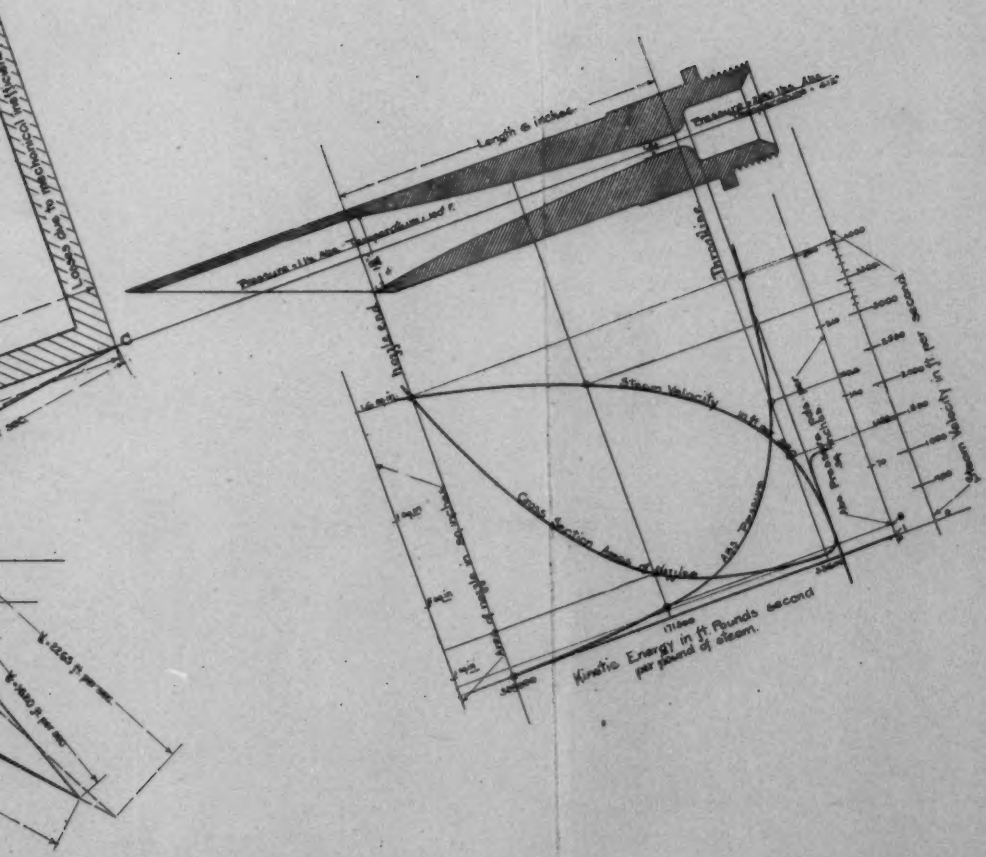
Note :-

Steam
- Dry saturated steam.
- Initial steam pressure = 280 lbs. ABS.
- Terminal " = 1 " = (28" Vac.)
- Temperature Range = 311° F.
- Mean Entropy = 1.17
- Total B.T.U.S. in steam = 311 + 1.71 = 360

Wheel
- Rev. per Min. = 10000
- Mean Diam. = 2.9"
- Bucket speed per sec. = 1266 ft.
- B.H.P. = 500

The De
Diagram of Velocity. Pre

Fig




The DeLaval Nozzle.
of Velocity. Pressure. Area and Energy.

**Figure 4.**

the ideal velocities, the assumed frictional losses and consequent losses in velocity both in nozzle and buckets of a single-impulse wheel, and the resultant efficiencies, are also diagrammatically shown. Judging from the extremely high velocity attained, it may be readily inferred that even with a small ratio of expansion, or a very slight increase of outlet area over throat area, a considerable velocity results. For pressures below 70 pounds per square inch the parallel nozzle has been found more efficient than the expanding, and is used in all stages, except the first, of a Curtis marine turbine. The steam weight discharged is directly due to the throat velocity and the area at the throat as well as the specific volume, therefore the higher the initial steam pressure the greater the weight per unit of time and area. The energy of the jet, however, corresponds to the end velocity as well as the weight. Throat and end velocity is the same in parallel nozzles, but quite different in the expanding nozzle.

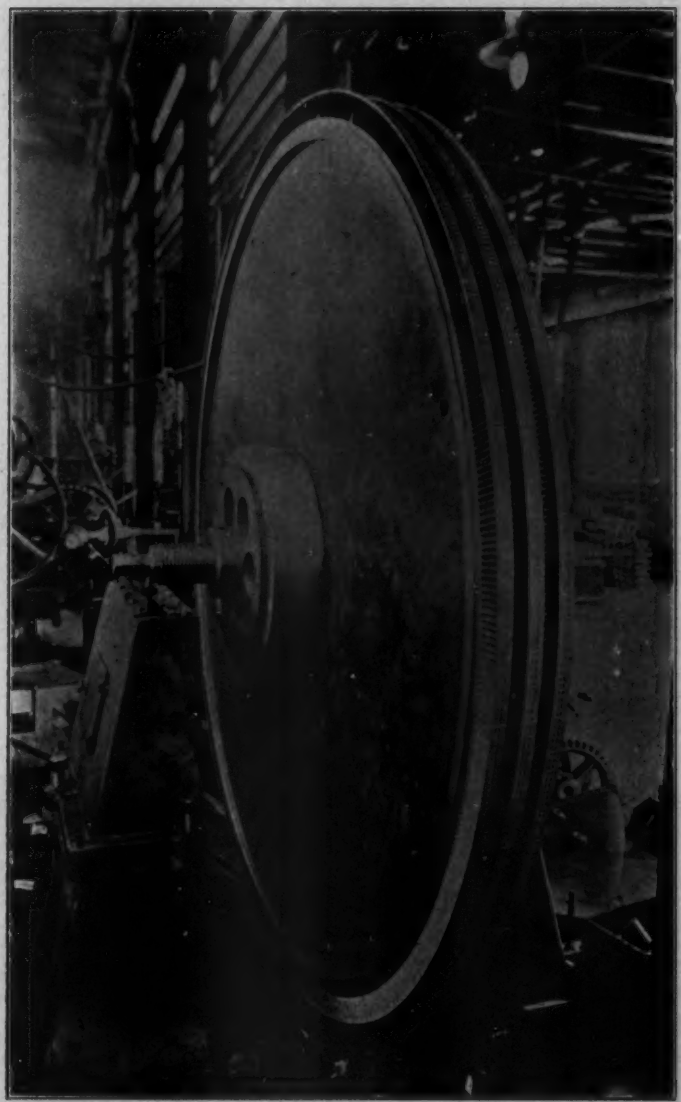
*Action.*—The Curtis marine turbine is of the compound-impulse type. The steam expands in seven sets of nozzles or pressure stages successively from the initial pressure to that of the exhaust. The first pressure stage, as has been mentioned, develops one-fourth the total energy, the other six each one-eighth. The jet energy is transformed into work by impulse on the moving discs, which, according to the jet velocity used, are arranged in from three to four velocity stages. Good efficiency demands that certain proportions of steam and bucket velocity be observed throughout the turbine.

The steam action is essentially as follows: After expansion in the nozzles of the first stage the steam issues in solid jets against the first row of moving buckets, which absorb a part of the jet energy, and, after passing through said buckets, meets the first row of stationary vanes. The purpose of these vanes is to guide the steam into the second row of moving buckets, which, in their turn, take up another portion of the kinetic energy still possessed by the fast flowing steam, at the same time diverting it into the second row of stationary buckets, which deflect the steam on the third row of moving buckets,

where again more of the energy is taken up. In the first stage, where the initial nozzle velocity is considerably higher than in any subsequent stage, this operation is again repeated in a third stationary row and a fourth moving row, the remaining energy after that being too small to warrant additional buckets. The pressure at the outlet end of the nozzles is brought down to the pressure within each stage by slight expansion in the various rows of buckets, the volume of the steam corresponding to successive pressures. However, due to the fact that the velocity of the steam is gradually diminished by the continuous absorption of energy, the passages traversed by the steam must be enlarged. This is provided for by lengthening the buckets as well as by increasing the vane angles in each succeeding row.

After leaving the last row of moving buckets in each stage the steam attains partial rest before it enters the nozzles of the next stage, in a manner similar to that which occurs between each "expansion" of a Parsons turbine. On entering the nozzles of the second stage the steam again expands, whereby new velocity is given, and now acts in the various rows of buckets of that stage exactly as it did in the first stage, and so on right through all of the seven stages of the turbine. There is this difference, however, that, owing to the nozzle velocity being very much less in the stages succeeding the first, three moving and two stationary rows will suffice there instead of respectively four and three of the first stage. The number and size of the nozzles in the different stages must obviously conform to the velocity and the volume of the steam as a result of expansion through the turbine. Due to this fact we find the nozzles circumscribing only a small arc in the first stage, gradually increasing in the following, until, in the last stage, the entire circle is completely filled with nozzles. This latter condition, however, is governed wholly by the power in comparison with the rotor diameter.

Steam velocities through the buckets of the first stage relatively to a fixed vane speed are shown diagrammatically in Figure 5. No account has been taken of velocity increase



ROTOR WHEEL MOUNTED ON TEMPORARY SHAFT, TO ASCERTAIN STATIC BALANCE.

as a result of expansion in the buckets in this diagram, which must be done in figuring vane dimensions. In the diagram shown in Figure 7, laid out for the seventh stage, this change is observed.

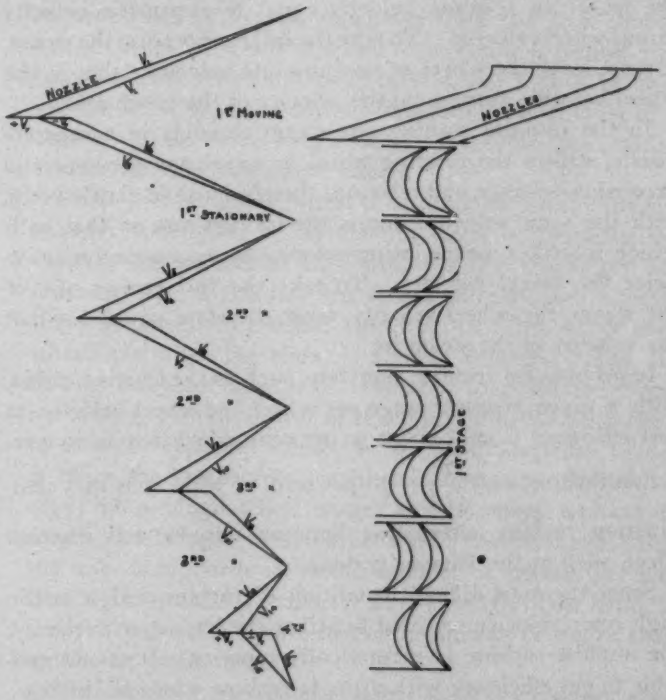



**Figure 5.**

VELOCITY DIAGRAM, 1ST STAGE. EXPANSION WITHIN BUCKETS NOT FIGURED.

*Calculation.*—In a steam turbine, the potential energy of the admitted steam is converted into kinetic energy of the steam jet and the kinetic energy of the steam jet into impulse force on the revolving wheel. This double transformation can take place either simultaneously in the same wheel (reaction turbine), or successively in stationary nozzles and revolving wheels (action or impulse turbine).

In the reaction turbine, steam enters the revolving wheel at admission pressure at moderate velocity, expands in the wheel and leaves the wheel at the velocity of expansion relatively to the wheel, that is, in a vane completely reversing the jet, at an absolute velocity equal to expansion velocity minus wheel velocity. To take the full energy out of the steam, it must leave the wheel at zero absolute velocity; that is, the wheel velocity must equal the velocity of the steam jet.

In the impulse turbine, the steam expands in a separate nozzle, strikes the rotating wheel at expansion pressure and expansion velocity, and rebounds therefrom, as an elastic body, with the same velocity, minus the friction loss, as that with which it strikes, hence losing velocity by an amount equal to twice the wheel velocity. To take the full energy out of the steam, the wheel velocity must therefore equal one-half the velocity of the steam jet.

In an impulse turbine, therefore, such as the Curtis turbine, with a given pressure range per wheel, the wheel velocity at best efficiency is only about 50 per cent. of what it is in a reaction turbine, and $\frac{1}{\sqrt{2}} = 70$ per cent. of what it is in a combination turbine alternating between impulse and reaction effect, such as the Parsons turbine.

Since the most difficult condition of turbine design is the high rotor velocity required to utilize the high steam velocity, the impulse turbine is theoretically superior. It is not possible to get efficiency with a single turbine wheel of the reaction type, while with a single wheel of the impulse type good efficiencies have been reached by using extremely high peripheral speeds (DeLaval turbine). In general, however, while hydraulic turbines are always designed with a single wheel, in the steam turbine it is not possible to make effective use of the total energy of the steam by a single wheel, but a number of wheels in series have to be used. That is, the rotor velocity is reduced by subdividing the total pressure range into a number of successive stages. In the combination impulse and reaction turbine of Parsons, each expansion or

pressure stage requires a revolving wheel and a stationary guide wheel, the steam acting by impulse at entrance and by reaction at the leaving edge.

In the impulse turbine, in which the expansion of the steam is carried out in nozzles separately from the vane system, a further effective means of speed reduction is presented by the use of several velocity steps in each stage; that is, by imparting the velocity of the current of steam to a number of successive wheels composing a single revolving disk, with stationary intermediate guide wheels.

Since in a revolving wheel of an impulse turbine the steam velocity is reduced by an amount equal to twice the wheel velocity for maximum efficieney, a single wheel per stage must revolve at one-half the steam velocity, two wheels per stage at one-quarter steam velocity, etc. The use of several wheels per stage, therefore, is a more effective means of reducing the rotor speed—or inversely, at given rotor speed, reducing the total number of revolving wheels—than the use of several expansion steps. A two-wheel stage can take care of twice the steam velocity (that is, four times the steam energy) of a single-wheel stage, and therefore replaces four single-wheel stages; or, in other words, the speed reduction of the rotor is proportional to the number of wheels per stage, that is, the number of velocity steps; on the other hand, it is proportional to the square root of the number of stages, that is, number of pressure steps.

The simultaneous use of pressure steps, or expansion stages, and velocity steps, or number of wheels per stage, therefore leads to a construction requiring a comparatively small total number of wheels, as carried out in the Curtis type of turbine.

The steam weight ($W$) passing (rate of flow) through a turbine nozzle depends principally upon:

1. Throat area $= A$ (in square inches),

2. Specific volume of the steam after expansion $= v$ (in cubic feet per pound),

3. Velocity of flow at the throat $= V$ (in feet per second), and is expressed by

$$W = \frac{A \times V}{v \times 144}, \quad \ldots\ldots\ldots \quad (1),$$

in which

$W$ = weight in pounds discharged per second.

The velocity at the throat corresponds to the thermo-dynamic head made up of the difference between the total heat of the entering steam and the total heat corresponding to the throat pressure, when the steam expands adiabatically. The throat pressure, for maximum flow, must be equal to, or less than $\cdot 577\ P_1$, when $P_1$ signifies the initial pressure. Owing to steam friction in the nozzle the velocity becomes somewhat less than if no diminution of heat conversion occurred, and must be carefully taken note of. We will call the percentage loss due to friction $y$, and if the equivalent thermo-dynamic head is called $H$, we get $(1-y)\ H$ representing the head creating kinetic energy.

$H$ is most readily obtained by aid of the ordinary entropy-temperature diagram, shown simply in Figure 6.

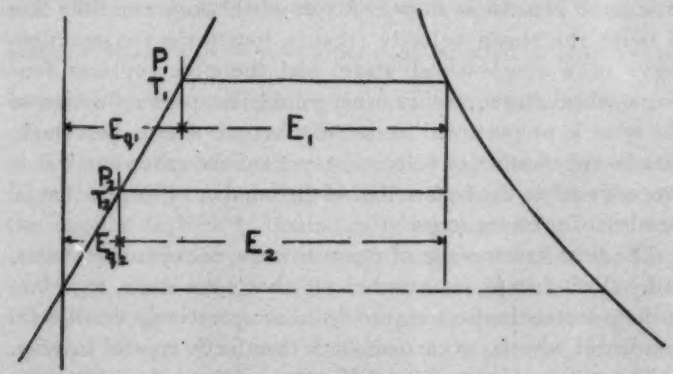



Figure 6.

We make

$P_1$ = initial pressure in pounds per square inch absolute;

$T_1$ = absolute temperature in degrees Fahrenheit corresponding to $P_1$;

$E_1$ = entropy corresponding to $P_1$ or $T_1$;

$P_2$ = throat pressure in pounds absolute = $\cdot 577\ P_1$;

$T_2$ = absolute temperature corresponding to $P_2$;

$E_2$ = entropy corresponding to $P_2$ or $T_2$.

The quantities for entropy are obtained direct from the steam tables, thus:

$E_1 = \frac{H_v}{T_1}$ when $H_v$ = heat of vaporization at $T_1$.

$E_2 = E_{\varphi 1} + E_1 - E_{\varphi 2}$, when $E_{\varphi 1}$ and $E_{\varphi 2}$ = entropy of the liquid respectively at $T_1$ and $T_2$.

We have the general formulae for the relation between kinetic energy and heat expressed by

$\frac{V^2}{2g} = 778\ (H_1 - H_2)$, in which

$V$ = velocity in feet per second,

$g = 32.16$.

$H_1$ = total heat of steam at $P_1$.

$H_2$ = total heat of steam at $P_2$.

The entropy curve being nearly a straight line, sufficiently close results will be obtained, for finding the available heat producing flow, by taking "mean entropy." We then get, observing friction,

$$V = 158\ \sqrt{(E_1+E_2)\ (T_1 - T_2)\ (1 - y)}, \quad . \quad . \quad (2)$$

which may be used for finding the velocity in any part of the nozzle.

Example:

Initial pressure = 265 pounds abs. = $P_1$; $T_1 = 867°$ F.,

Throat pressure = .577 $P_1$ = 152.8 pounds abs. = $P_2$; $T_2 = 820°$ F.,

$E_1 = .9524$,

$E_2 = 1.01$,

$y$, disregarded,

$V = 158\ \sqrt{1.9624 \times 47} = 1{,}517$ feet per second.

The steam weight passed, when

$A = .6156$ square inches,

$v = 2.96 \times \frac{1.01}{1.05} = 2.8416$ cubic feet, is

$W = \frac{.6156 \times 1517}{2.8416 \times 144} = 2.283$ pounds per second.

The steam velocity found above refers strictly to conditions of expansion set forth, and is attained at the throat of whatever kind of nozzle is used, divergent of parallel. For the parallel nozzle, in which the throat and outlet area are identical, the throat velocity and outlet velocity will be the same, and this velocity can, therefore, be used in finding the energy of the jet. In the divergent nozzle a farther expansion occurs within the nozzle between the throat and the outlet, and the velocity at the outlet, which determines the energy, corresponds to the total heat drop taking place between the orifice and the outlet. Thus, substituting for the throat pressure the pressure at the outlet in the first stage nozzles given in table 1, we get for $V$, disregarding friction,

$V = 158 \sqrt{(.9524+1.056)\,(867 - 784)} = 2{,}040$ feet per second, and when taking account of friction, assuming $y =$ 15 per cent,

$V_1 = 158 \sqrt{167\,(1 - .15)} = 1{,}881$. (See Figure 6.)

Tabulating the different quantities for the nozzles given in Table I, and figuring first, corresponding to $H$, disregarding friction, and second corresponding to $H^1$ assuming a certain value for $y$, we get

TABLE II.

| $E_1+E_2$ | $T_1-T_2$ | $H$ | $V$ | $H^1$ | $V_1$ | $Y$ | No. of stage. |
|---|---|---|---|---|---|---|---|
| 2.0086 | 83 | 167.0 | 2,040 | 142.0 | 1,881 | .15 | 1 |
| 2.3382 | 36 | 84.16 | 1,454 | 72.4 | 1,350 | .14 | 2 |
| 2.579 | 32 | 82.6 | 1,435 | 71.06 | 1,332 | .14 | 3 |
| 2.794 | 29 | 81.0 | 1,422 | 69.7 | 1,320 | .14 | 4 |
| 3.020 | 24 | 72.48 | 1,345 | 62.5 | 1,250 | .14 | 5 |
| 3.304 | 22 | 72.68 | 1,345 | 62.5 | 1,250 | .14 | 6 |
| 3.498 | 20 | 70.0 | 1,324 | 60.2 | 1,230 | .14 | 7 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | |

The cross-section of the nozzles used in Curtis turbines is rectangular, the expansion being obtained by the divergence of the walls of the nozzle. The energy developed per pound of steam per second in each, and corresponding to foregoing velocities, is:

1st stage $\frac{1881^2}{64.32}$ = 55,000 foot pounds,

2d stage $\frac{1350^2}{64.32}$ = 38,320 foot pounds,

3d stage $\frac{1332^2}{64.32}$ = 27,600 foot pounds,

4th stage $\frac{1320^2}{64.32}$ = 27,080 foot pounds,

5th stage $\frac{1250^2}{64.32}$ = 24,280 foot pounds,

6th stage $\frac{1250^2}{64.32}$ = 24,280 foot pounds,

7th stage $\frac{1230^2}{64.32}$ = 23,520 foot pounds.

Total, 220,000 foot pounds.

Assuming a uniform friction loss of eight per cent. in the vanes, then $y = .08$ and $V_a = V_e\sqrt{1-y}$, the following velocities in each vane row are obtained, reference being had to the velocity diagram shown in Figure 5, $V_a$ and $V_e$ in the formulae signifying respectively exit and entrance velocity from and to the vanes. No account of the increase in velocity due to expansion within the vanes being observed.

$V_1$ = 1881, nozzle velocity, absolute entrance,
$V_2$ = 1708, nozzle ($1_m$) velocity, relative entrance,
$V_3$ = 1637, vane ($1_m$) velocity, relative exit,
$V_4$ = 1464, vane ($1_e$) velocity, relative entrance,
$V_5$ = 1403, vane ($1_a$) velocity, relative exit,
$V_6$ = 1235, vane ($2_m$) velocity, relative entrance,
$V_7$ = 1184, vane ($2_m$) velocity, relative exit,
$V_8$ = 1017, vane ($2_e$) velocity, relative entrance,
$V_9$ = 975, vane ($2_a$) velocity, relative exit,
$V_{10}$ = 815, vane ($3_m$) velocity, relative entrance,
$V_{11}$ = 781, vane ($3_m$) velocity, relative exit,
$V_{12}$ = 637, vane ($3_e$) velocity, relative entrance,

$V_{13}$ = 611, vane ($3_s$) velocity, relative exit,
$V_{14}$ = 480, vane ($4_m$) velocity, relative entrance,
$V_{15}$ = 460, vane ($4_m$) velocity, relative exit,
$V_{16}$ = 350, vane ($4_m$) velocity, absolute exit,
$V_v$ = 183, angular vane speed.
All of foregoing velocities are in feet per second.

The kinetic energy loss with $y$ per cent. friction loss will be $\frac{yV_r^2}{2g}$ when $V_r$ is the relative entrance velocity in a moving row of vanes. Moreover, if the steam leaves the same row with an absolute velocity $V_a$ its energy is $\frac{V_a^2}{2g}$. Subtracting both losses from the energy caused by the initial jet velocity $V$, we have, for the work done upon any one of the moving buckets

$$\frac{V^2}{2g} - \frac{yV_r^2}{2g} - \frac{V_a^2}{2g}.$$

Tabulated for foregoing velocities, the work done per pound of steam in the first stage will be in foot-pounds second:

First moving buckets,

$$\frac{1}{2g}\left\{ V_1^2 - .08V_2^2 - V_4^2 \right\} = \frac{1{,}881^2 - .08 \times 1{,}708^2 - 1{,}464^2}{64.32} =$$

17,930 foot pounds.

Second moving buckets,

$$\frac{1}{2g}\left\{ V_5^2 - .08V_6^2 - V_8^2 \right\} = \frac{1{,}403^2 - .08 \times 1{,}235^2 - 1{,}017^2}{64.32} =$$

12,600 foot pounds.

Third moving buckets,

$$\frac{1}{2g}\left\{ V_9^2 - .08V_{10}^2 - V_{12}^2 \right\} = \frac{975^2 - .08 \times 815^2 - 637^2}{64.32} =$$

7,644 foot pounds.

Fourth moving buckets,

$$\frac{1}{2g}\left\{ V_{13}^2 - .08V_{14}^2 - V_{16}^2 \right\} = \frac{611^2 - .08 \times 480^2 - 350^2}{64.32} =$$

3,570 foot pounds.

Total = 41,744 foot pounds.

Assuming (without detail figuring) the original proposition is realized, namely, that each subsequent stage following the first develops one-half the power of the first, we have for the work in the whole turbine converted into heat units:

| | | | |
|---|---|---|---|
| 1st stage = | 41,744 foot pounds = | 53.6 B.T.U. |
| 2d stage = | 20,872 foot pounds = | 26.8 B.T.U. |
| 3d stage = | 20,872 foot pounds = | 26.8 B.T.U. |
| 4th stage = | 20,872 foot pounds = | 26.8 B.T.U. |
| 5th stage = | 20,872 foot pounds = | 26.8 B.T.U. |
| 6th stage = | 20,872 foot pounds = | 26.8 B.T.U. |
| 7th stage = | 20,872 foot pounds = | 26.8 B.T.U. |
| Total all stages = | 166,976 foot pounds = | 214.5 B.T.U. |

The losses throughout the turbine will then be about as follows:

From the efficiency given, or 51.52 per cent., the total losses = 48.48 per cent.

| | |
|---|---|
| Friction loss in nozzles = | 14.14 per cent. |
| buckets = | 8.00 per cent. |
| Loss due to exit velocity = | 9.53 per cent. |
| | 31.67 per cent. |

Deducting this from total losses, loss from all other sources will be 48.48—31.67 = 16.81 per cent.

Horsepower developed per pound of steam $\frac{167,000}{550} = 304.$

Steam quantity required for 7,460 horsepower $\frac{7,460}{304} =$ 24.54 pounds per second.

Steam per horsepower-hour $\frac{1,980,000}{167,000} = 11.84$ pounds.

Actual experiments with turbines of this type, (with, however, only three revolving rings of buckets in the first stage, and developing only about 1,200 horsepower) have demon-

strated that 14 pounds are needed, the difference, or 2.16 pounds, is therefore, the amount required to overcome other losses previously enumerated.

Energy by reheating of the steam on account of friction and the impact by the exit velocity is given back to a subsequent stage in form of heat by raising the quality of the steam. This amount may be accurately figured and the results obtained used in determining the blade dimensions, as well as the heat to be expended in the various stages.

Referring to Table I it will be noticed that the nozzle end pressure is higher than the shell pressure. In traversing the vane path a successive drop of pressure must, therefore, occur. The expansion taking place between the rows will in all likelihood somewhat mitigate the effect of friction and slightly increase the velocities. A difference of pressure on each side of the vanes over an arc covered by the stationary buckets does set in at the same time, whereby a slight end pressure on the rotor, opposite in direction to the propeller thrust, is exerted.

*Determination of blade and nozzle dimensions.*—For the example chosen the mean vane diameter was taken to be 83 inches, the horsepower of each turbine equivalent to 7,460 brake and the initial steam pressure about 265 pounds absolute, with 28 inches vacuum.

Since the horsepower primarily depends upon the steam quantity and the energy developed by its velocity, a sufficient number of nozzles, of dimensions such as to give the proper pressure range for each stage, must first be provided. For 7,460 horsepower at 14 pounds per hour, steam per second required equals 29 pounds.

Using velocities previously given for the first-stage nozzles and making $y = .15$, the area at the throat must be, formula (1),

$$A = \frac{29 \times 2.8416 \times 144}{1{,}517\sqrt{1 - .15}} = 8.21 \text{ square inches,}$$

making each nozzle $= .6156$ square inches.

$$\text{Number of nozzles} = \frac{8.21}{.6156} = 13.3.$$

Turbines are generally made for considerable overload, even up to 50 per cent., which, if followed out here, would give about 20 nozzles.

The area of the nozzle end is figured for the same steam weight, but the velocity being considerably greater, or 1,881 feet against 1,491 feet, and the specific volume corresponding to the lower pressure and quality due to expansion being 4.294 against 2.841, we get for the nozzle end,

$$A_1 = \frac{29 \times 4.294 \times 144}{1{,}881} = 10 \text{ square inches, or for each}$$

$$= \frac{10}{13.3} = .76 \text{ square inches.}$$

The vane angles should be those given by the velocity diagram, one of which must be laid down separately for each stage. The passage area between the vanes must correspond with the velocity at each point as well as the actual volume. This must be figured for both quality incident to frictional disturbance and adiabatic expansion. A small amount is added to the length of the vane at each step over what is necessary for actual area in order to catch the steam separated from the jet in spreading and leakage.

The passage area between the vanes may be determined in the following manner. Owing to the fact that the volume is greatest after expansion in the last stage and the velocity is smallest at the last row, the buckets at this point become longest and, therefore, in a measure settle the outside diameter of the turbine. The dimensions of these buckets should be figured first on that account.

The velocity diagram, Figure 7, is laid down with the actual exit velocity from the nozzle as jet velocity. Referring to Table I, the pressure at the nozzle end is 1.27 pounds absolute and in the shell about 1 pound absolute, therefore a drop of .27 pound between the inlet of the first buckets and the outlet of the last. This pressure drop for adiabatic expansion is equivalent to 11 B.T.U., which we may assume is equally absorbed among the five rows, thus in each 2.2 B.T.U.

The relative entrance velocity to the first moving buckets

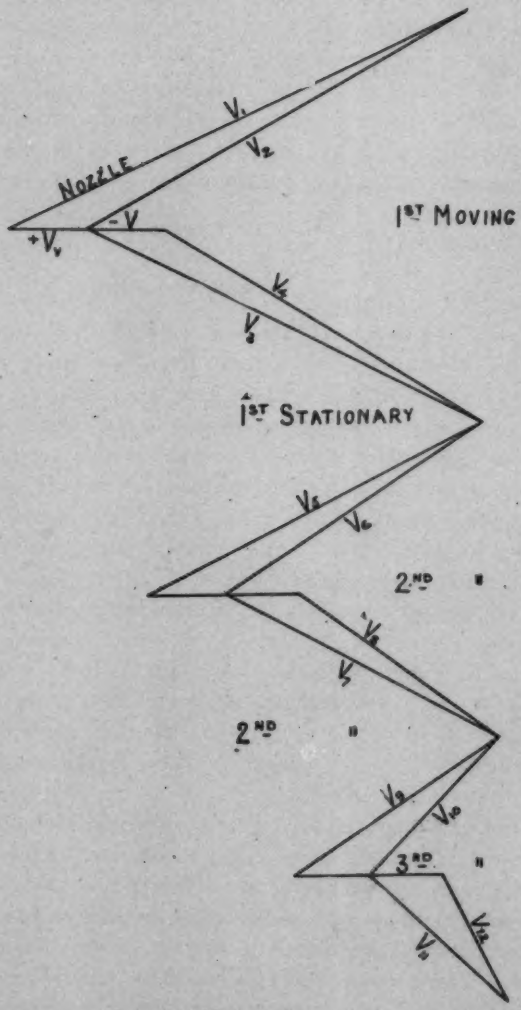



**Figure 7.**

VELOCITY DIAGRAM, 7TH STAGE, EXPANSION WITHIN BUCKETS OBSERVED.

is 1,065 feet from the diagram. Assuming a friction loss of 9 per cent. both in the energy of the steam passing the vanes and in the heat given up by the steam in transit, we get

$$\frac{V_3^2}{2g} = .91 \times 778 \times 2.2 + \frac{V_2^2}{2g} \times .91,$$

$$V_3 = \sqrt{64.32 \times .91 \times 778 \times 2.2 + 1{,}065^2 \times .91} = 1{,}065$$

feet per second.

In arranging for a slight steam expansion within the buckets, provided for by an excess of nozzle end pressure over shell pressure, an increased velocity is attained, rendering possible a reduction in their length with the same clear space between them as would be required otherwise with the longer bucket.

Vane speed being given and exit angle determined upon, $V_4$ is drawn in. The diagram is figured similarly right through for the remaining rows, whereby is found $V_{11}$, the relative exit velocity from the last row to be 460 feet. The pressure within the row at the point of smallest section equals about 1.016 pounds absolute.

Corresponding volume = 316 cubic feet.

Corresponding quality = .79.

Corresponding clear space between two buckets = .5365 inches.

$$\text{Number of spaces} = \frac{261}{.66} = 400;\ 261 = \text{mean circumference},$$

and .66 = space occupied by a bucket and an opening in inches.

Total steam volume = $.79 \times 316 \times 2g = 7{,}240$ cubic feet.

$$\text{Area of steam flow} = \frac{7{,}240}{460} = 15.7 \text{ square feet.}$$

$$\text{Length of blade} = \frac{15.7 \times 144}{400 \times .5365} = 10.14 \text{ inches.}$$

All blade or bucket passages may be determined in the same way, observing that the height of the first row must be made to conform with the nozzles.

*Application.*—Up to date no actual trials have been performed with the multiple-stage marine turbine of the modern Curtis type. A number of such turbines, however, are now

under construction, both for mercantile and naval purposes, most of which are now in a state of completion, such that early trials are anticipated. Among those alluded to, the following are of particular interest:

U. S. scout cruiser *Salem* of 16,000 horsepower, to make 24 knots with the propellers revolving at 350 turns per minute.

The Southern Pacific mail steamer *Creole* of 17 knots and 8,000 horsepower and a propeller speed of 235 revolutions.

Two sets of two units, each of about 25,000 horsepower combined, for the Japanese Navy.

A naval launch of about 250 horsepower.

All of the foregoing are being built by the Fore River Shipbuilding Company of Quincy, Mass.

The Hamburg-American liner *Kaiser*, equipped with Curtis turbines of a type adopted by the Allgemeine Electricitäts Gesellschaft of Berlin, has been in commission for some time, and is giving, it is believed, general satisfaction. Her tur-

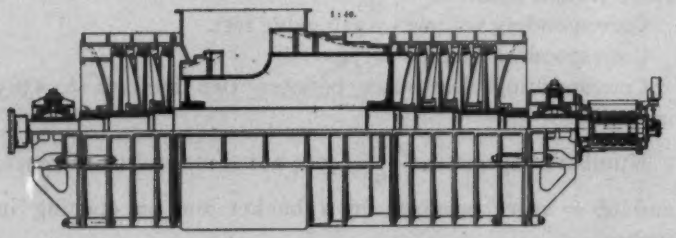


Figure 8.

bines consist, in the high-pressure zone, of five pressure stages, each with about three moving rows of buckets, while in the low-pressure zone there are some twenty pressure stages, each with a velocity stage or moving row. The reversing end of the turbine, figured for 50 per cent. of the full power, contains two pressure stages, each of which has three rows of moving buckets. Figure 8 shows a turbine in which is incorporated features of both Curtis and Parsons, while the *Kaiser's* turbines seem to possess features like the Zoelly.

The following items are especially interesting with respect

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to the impulse type of turbine in review with the compound reaction type:

1. For a given bucket speed and pressure range the number of vane rows is considerably less in the former than in the latter.

2. The steam expansion being executed in nozzles renders possible the use of high initial pressures, as well as superheat, without affecting detrimentally the turbine cylinder from excessive stress, or the vane system from distortion incidental to superheat.

3. Aside from throttle-valve regulation the steam supply may be varied, to suit any degree of power to be developed by the turbine, by shut-off valves on the nozzles, eliminating thereby the necessity for separate cruising turbines as now usually arranged for in war ships.

4. Large clearances are used in Curtis marine turbine at both side and end of blades, thus minimizing the danger of fouling of buckets from displacement of shaft or vibratory influences.

5. Balance or dummy pistons, to equalize end pressure, do not exist in the impulse marine turbine, and a source of loss as well as the necessity for delicate adjustment is eliminated.

6. For the same total power propeller diameters are larger in twin-screw ships fitted with Curtis turbines than in vessels of triple or quadruple screws with Parsons. The capacity for maneuvering is increased by using larger propellers and by making available all of the blade area, against the two-thirds to one-half provided for in turbine ships of latter screw arrangement. Backing turbines are, however, fitted on each shaft in quadruple screw arrangements of naval ships.

It is needless to say that the trials of the Curtis marine turbine will be watched with keen interest, and, if the performance may be prejudged, success is predicted. Economy, natural advantage in application, saving of weight and space, should render this type of turbine especially serviceable.

# SUGGESTIONS FOR THE CARE AND OPERATION OF NAVAL MACHINERY IN THE ENGINEER DEPARTMENT, U. S. NAVY.

By H. C. Dinger, Lieutenant, U. S. N., Member.

## PART IV.

### PIPING.

The various piping systems are among the chief items for care and repair on board ship. The following general information with regard to the latest practice of the Bureau of Steam Engineering is given.

#### PIPE FLANGES AND FITTINGS.

"The dimensions of all flanges will be in accordance with the Bureau of Steam Engineering table of flanges.

"There will be no screw joints in steel steam piping. The joints will be made by flanges of stamped or forged mild steel of the same quality as specified for steel steam pipes. The pipe will be either welded to the flange or else rolled into the flanges and beaded over to fit a recess flush with the face of the flange, in accordance with the practice of the Bureau of Steam Engineering. All flanges will be faced and grooved.

"Copper pipes will have flanges or approved composition couplings brazed on, and the end of the pipe will be beaded into a recess in the face of the flange.

"All copper pipes below the floor plates will have composition flanges.

"All joints between flanges in steam and exhaust pipes will be made with corrugated-copper gaskets.

"All joints between flanges in water pipes will be in accordance with Navy Department Standard No. 86, 'Method of

making joints and of obtaining water-tightness through bulkheads, decks, etc.'

"All flanges on the main drain connections to the main circulating pumps, and Construction and Repair drainage manifolds for connection with steam machinery, will be located to the satisfaction of the Bureau of Steam Engineering and the Bureau of Construction and Repair.

"Flanges for wrought-iron or steel pipes, for salt water, to be cast or wrought steel, galvanized.

"Fittings for steel steam pipes will be of cast steel, Class B, or composition.

"Fittings for copper pipes will be of composition unless otherwise directed.

"Fittings for wrought-iron or steel pipes, for salt water, to be of cast-iron or steel, galvanized.

"Pipes will be so led and flanges so placed that they may be readily taken down for renewal or repairs, and so that joints will be kept readily accessible.

"All external fittings on boilers will be composition unless otherwise directed, and will be flanged and through-bolted, or attached in other approved manner.

"All internal pipes will not touch the boiler plates anywhere, except where they connect with their external fittings. The internal feed and blow pipes will be expanded in the holes in boiler shells to fit the nipples on their valves, or will be secured in other approved manner, and will be supported where necessary and as directed.

"All internal pipes and fittings of brass, copper or composition will be tinned.

"All copper pipes intended to convey salt water will be protected on the inside by coats of asphaltum or other approved waterproof varnish, applied as hot as possible and in successive coats.

"All copper pipes in bilges will be well painted, and will not rest in contact with any of the iron or steel work of the vessel.

"All wrought-iron and steel pipes and tubing, for salt water,

to be galvanized after they have been bent and flanges fitted.

"Care will be taken that all copper pipes are led sufficiently high to keep them out of the bilge water under ordinary circumstances.

"Feed pipes will be placed, where possible, well above the floor plates.

"Pipes will be led in such a manner that no stiffeners on bulkheads or beams on decks will have to be cut.

"Removable plates will be fitted on bulkheads where necessary to allow flange bolts to be properly set up; these plates to be fitted and made watertight to the satisfaction of the Bureau of Construction and Repair.

"Where pipes pass through watertight bulkheads the holes will be made watertight, by stuffing boxes, flanges, or other approved means, to the satisfaction of the Bureau of Construction and Repair. In no case will any of the watertight structure of the vessel form a part of the piping.

"Where pipes pass through wooden decks, they will be fitted with a hollow casting and a stuffing box, so arranged that nonconducting material may be fitted between movable and fixed parts, the details to be satisfactory to the Bureau of Construction and Repair.

"Where pipes pass through coal bunkers they will be protected by galvanized-iron casings, made in sections, easily removable for repairs.

"When such pipes are clothed or lagged the galvanized-iron casing will be dust tight.

"Pipes will not be led under openings of coal chutes.

"*Material of Pipes.*—Pipes will be of the following materials:

| *Pipes.* | *Material.* |
|---|---|
| All pipes less than 2-inches diameter. | Copper, unless otherwise directed. |
| All steam pipes 2-inches diameter and above. | Steel, seamless drawn. Copper when directed by Bureau. |
| All feed suction pipes..... | Copper, seamless drawn. |
| All feed discharge pipes..... | Copper, seamless drawn. |
| Pipes to reserve feed-water tanks..... | Lap-welded wrought-iron or steel tubing, galvanized. |
| All steam, air and water pipes of refrigerating plant. | Copper, unless otherwise directed. |

| *Pipes.* | *Material.* |
|---|---|
| Steam fire-extinguishing pipes to bunkers, outside bunkers. | Copper. |
| Steam fire-extinguishing pipes to bunkers, inside bunkers. | Galvanized iron. |
| Cooling pipes in refrigerating room. | Galvanized iron. |
| Cooling pipes in scuttle butts..... | Copper, well tinned on the outside. |
| Suctions from bilge, crankpits, shaft alleys, and C. and R. drainage manifolds. | Lap-welded wrought-iron or steel tubing galvanized. |
| All internal pipes in boilers..... | Brass or steel, No. 14 B.W.G. |
| All water-service pipes on main or auxiliary engines. | Brass, polished above floor plates. |
| Copper and brass pipes 6 inches diameter and less. | Seamless drawn. |
| Other pipes..... | As directed and approved. |

"*Thickness of Pipes.*—All pipes will be of approved size.

"The thickness of pipes will be found by the following formulae:

"For straight copper pipe—

$$T = \frac{P \times D}{8{,}000} + \frac{1}{16} \text{ inch.}$$

"For steel steam pipe—

$$T = \frac{P \times D}{10{,}000} + \frac{1}{8} \text{ inch.}$$

Where $P$ = pressure above atmosphere in pounds per square inch;

$D$ = inside diameter of pipe, in inches;

$T$ = thickness, in inches.

"For the following pipes:

| Pipes. | P = |
|---|---|
| Steam, bleeder, blow pipes, suction pipes from boilers, | 265, boiler pressure. |
| Feed discharge pipes..... | $1\frac{1}{4} \times 265$. |
| Fire main connections, copper water-service pipes, feed-suction pipes..... | 150. |
| Other water pipes without pressure..... | 50. |
| Exhaust pipes $4\frac{1}{2}$ inches diameter and less ..... | 20. |
| Exhaust pipes above $4\frac{1}{2}$ inches diameter..... | 50. |

"All pipes not included in the above will be of approved thickness.

"No bend will be allowed in copper pipes of which the radius is less than one and one-half times the bore of the pipe. Bends in steel pipes will be as approved.

"In determining the thickness of bent pipes the neutral axis will be considered to lie on the inner surface of the bend, and when, in bending, the outer surface is reduced in thickness more than $\frac{1}{32}$ inch, the pipe must be one gage thicker than given by formula.

"*Expansion or Slip Joints.*—Compostion.

"Expansion or slip joints of approved pattern will be fitted where required, and connecting pipes will be anchored in an approved manner. Each slip joint will consist of a composition stuffing box, gland, and entering pipe, the stuffing box and entering pipe having flanges for connecting with the pipe main, and there will be stop bolts and flanges for limiting the motion.

"All slip joints will be packed with approved metallic packing.

"All steam, exhaust and feed piping not fitted with slip joints will be run as approved, with ample bends, to provide for expansion. Such pipes will be so fitted as to put them under stress when cold by allowing for every 10 feet of length when bolting up a clearance between flanges of $\frac{1}{16}$ inch for steam pipes and $\frac{1}{32}$ inch for exhaust and feed pipes.

"*Systems of Piping.*—There will be the following systems of piping, together with such others as may be necessary to complete the machinery in accordance with the specifications and plans, viz:

"Main steam and exhaust piping; auxiliary steam and exhaust piping, with branches to all auxiliary and special steam machinery in the vessel; bleeder pipes; live-steam pipes to intermediate and low-pressure receivers; dynamo steam and exhaust piping; main-feed suction and discharge piping; auxiliary-feed suction and discharge piping; bilge suction and discharge piping; sea suction and discharge piping; fresh-water suction piping and discharge pipes to reserve-feed water tanks; discharge piping from pumps to fire mains and sanitary

system; water-service piping; boiler blow, pumping-out, and internal piping; distiller and evaporator piping; vapor, escape, drain, indicator, radiator, and fire-extinguishing piping, and steam piping to sea valves, refrigerator piping complete.

"Each system will be complete in itself, and all piping, together with valves, fittings and connections, will be shown on the working drawings."

### PIPING SYSTEMS.

The following systems are met with in the Navy.

Main steam-pipes are made of seamless-drawn steel, with male and female flanges, and with gaskets of corrugated copper. The main steam line is arranged symmetrically in two systems, one on each side of the vessel. The branches from the boilers connect to the main steam pipe, which is successively enlarged till it connects to the after boilers, which size is then carried to engine room. Stop valves are fitted near the forward bulkhead of each boiler compartment for the purpose of cutting out any boiler room. Cross connections between the two systems are made generally at two joints, these are fitted with valves so that each system can be kept separate.

Inside the engine-room bulkhead there is another cross connection. A separator is fitted for each engine, also a bleeder connection to condenser, a connection to the auxiliary exhaust line, a branch for live steam to receivers and the branch leading to the throttle valve in which the main-engine stop valve is located.

Expansion joints are fitted generally between each bulkhead, and should have such a joint between each point of anchorage.

Drains are fitted to all places where water may collect, and these are usually connected to traps, which discharge to feed tanks.

Auxiliary steam pipes are of seamless-drawn steel, with male and female flanges, and gaskets of corrugated copper, except for pipes of small diameter where rubber insertion or strengthened asbestos packing is used.

In the latest practice the auxiliary steam pipe takes steam

from the nozzle at the cross connection between the main steam pipes in engine room. The pipes pass along outboard sides of engine room and form a connecting loop. A branch pipe leads aft to supply steam to the after auxiliaries, expansion joints or expansion bends are fitted at intervals, drains and separators are fitted where pockets are formed.

From the forward cross connection of main steam pipe in boiler rooms there is a branch pipe to supply steam to forward auxiliaries.

*Branch Steam and Exhaust Pipes.*—The general requirements for these may be seen from an extract of latest machinery specifications.

BRANCH STEAM AND EXHAUST PIPES AND VALVES.

"The size and lead of branch pipes to parts of ship outside of the machinery spaces will be subject to the approval of the Bureau of Steam Engineering. Such branches will always have stop valves in the engine or firerooms.

"1-inch branches from the auxiliary steam pipes will lead to the bottoms of main, auxiliary and dynamo condensers for cleaning the tubes by boiling.

"Connections will be made to the auxiliary steam pipe for supplying steam to sinks, steam table in pantries and crew's lavatories.

"Steam for galleys will be taken from the auxiliary steam pipe, through a separate pipe with reducing valves, steam gauge, relief valve and stop valves where approved.

"Each sea injection valve will have a steam connection of approved size for cleaning the strainer. This steam connection will be a branch pipe, with a valve at each end, leading from the auxiliary steam pipe to the injection pipe outside of the injection valve but inboard of the sea chest proper.

"Steam pipes to sea valves will be of the following sizes:

| Size of sea valves. | Steam connections. |
|---|---|
| 6 inches and less | ¾ inch. |
| Above 6 inches and including 9 inches | 1 inch. |
| Above 9 inches and including 12 inches | 1¼ inches. |
| Above 12 inches | 1½ inches. |

"All branches leading from the auxiliary steam pipe to crank engines will lead from the top or side of the pipe and in no case from the bottom. When the branch leads to a lower level the stop valve on the branch will be placed as high as possible, so that with the engine standing idle there will be no opportunity for water to collect in the vertical pipe leading to it.

"All branches leading from the auxiliary steam pipe to direct-acting pumps will lead from the bottom of the pipes.

"All auxiliary machinery will take steam from the auxiliary steam pipe and exhaust into the auxiliary exhaust pipe, except as follows:

| Engine. | Takes steam from. | Exhausts into the— |
|---|---|---|
| Main circulating pumps, fire and bilge pumps, reversing engines. | Cross-connection pipe between the the main and auxiliary steam pipes. | Auxiliary exhaust pipe. |
| Main air pumps..... | Cross-connection pipe between the main and auxiliary steam pipes. | Do. |
| Brine pump..... | Auxiliary steam pipe, also from evaporator tubes near discharge to traps, or from top of traps, to prevent the evaporators from becoming air bound. | Do. |

"All branches and sub-branches of auxiliary steam and exhaust pipes must (unless excepted) have valves at junctions and ends.

"Each auxiliary engine will have stop valves in both steam and exhaust pipes, as close to the cylinder as possible.

"When a pump or an engine, connected with the auxiliary exhaust pipe, lies below the pipe, the stop valve next the pipe will have a spindle of sufficient length to be worked from below.

"All exhaust pipes leading to the condenser from engines above the protective deck will be fitted with valves below the protective deck."

FURTHER DETAILS.

Such auxiliaries as require it have their branch steam lines fitted with reducing valves.

The former practice was to have the auxiliary steam pipe

connect to all the main stop valves, and a connection from auxiliary steam line to main steam line in each boiler room. This is the system installed on most vessels now in commission (January, 1906).

*Auxiliary Exhaust Pipes* are of copper, having flanges faced and grooved, steel bolts, composition nuts, copper gaskets, except for small pipes where strengthened rubber packing is used.

The auxiliary exhaust line forms a loop throughout the machinery compartments. All of the auxiliary engines have connections to it.

The auxiliary exhaust has connections so that it can be turned into either main or auxiliary condenser, into either L.P. receivers, into either feed-water heater or, into the atmosphere through the after escape pipe.

At the connections to the condensers there is a stop valve and a spring relief valve opening toward the condensers for the purpose of regulating the pressure in the exhaust line when the exhaust is turned into feed the heater or L.P. receivers. At the connection to the escape pipe two valves are generally fitted to minimize the chance of air leaks.

On older vessels, especially where no feed-water heaters are installed, spring relief valves are not fitted on the connection to the condensers.

Dynamo steam and exhaust pipes are of same material as auxiliary steam and exhaust pipes.

The latest practice is to have two dynamo rooms, one forward and one aft. The steam is then taken from the forward cross-connection of main steam line and from a connection in after boiler room. The control valves are in the dynamo rooms. Separators and reducing valves are fitted in dynamo room, and drain pipes and traps supplied. The pipes are so arranged that in case of break at least one-half of the dynamo engines in each room may be operated.

The exhaust from the dynamo engines can be directed to the dynamo condenser or to the auxiliary exhaust pipe.

In older vessels there are often fitted on boilers, separate

dynamo stop valves with a special system of piping. Separate dynamo condensers are only fitted on the latest vessels.

*Steam Piping to Receivers.*—This is taken from the main steam pipe and has branches leading to the I.P. and L.P. receivers. Stop valves are fitted close to main steam pipe and at each receiver, where the valve is operated by rod or lever from the starting platform.

*Bleeder Pipes.*—Bleeder pipes lead from the main steam pipe, forward of separator, to each main condenser. A stop valve is fitted at the connection to the main steam pipe, and there is another valve close to the condenser. One of these valves is fitted to be operated from or near the starting platform.

*Escape Pipes* are fitted abaft of each smoke stack and have branches leading to the safety valves of the boilers connected to their respective smoke stacks. The after escape pipe has a connection to the auxiliary exhaust line.

Vapor pipes are led from the feed and filter tanks and connect to the after escape pipe. The purpose of these pipes is to ensure an atmospheric pressure in feed tanks and to allow escape of air.

*Pipes to Whistle and Siren.*—These are branch pipes leading from the main or auxiliary steam pipes in the boiler room from some point that is likely to be always under steam.

*Fire-Extinguishing Pipes to Bunkers.*—These pipes lead from the main or auxiliary steam line to the bunkers and have valves at the bunker bulkheads. Bunkers above the protective deck sometimes have valves worked from the deck above by gearing. The pipes in the bunkers are fitted with special nozzles for distributing steam throughout the coal. In the latest practice this system is not fitted, and dependence is placed on fire hose or special water-sprinkling pipes.

*Automatic System of Closing Valves.*—On some late vessels the stop valves of boilers are closed by steam operating a piston connected to the valve, the system of piping for operating these valves takes steam from the main steam line. The control vaives are located so that they are operated from the adjacent boiler compartment or from a station above the boiler.

This system or variations of it have in some cases been of questionable utility and reliability. Direct mechanical control is generally regarded with more favor by the operating personnel.

*Fire-Extinguishers on Grates.*—This system of piping is fitted on recent vessels. Nozzles are fitted for the furnaces, and the piping is either connected to the fire main or from the auxiliary pumps in adjacent boiler compartment. In some vessels these extinguishers take their water from the sea valve.

*Separators.*—The object of the separator is to extract the moisture contained in the stack. This is generally accomplished by an enlargement of the volume and a sharp turn around a baffle plate. Other types of separators give the steam a whirling motion, and the particles of water are thrown out by centrifugal force. In practice the simple separator gives about as great satisfaction as the more complicated ones fitted with elaborate baffling systems.

Separators must be frequently drained and the interior should be examined from time to time and have the grease deposits removed.

*Expansion Joints.*—To allow for expansion and contraction in piping due to change of temperature and also for movement of the structure of the ship, vibrations, etc., expansion joints are fitted. The joints are packed with metallic packing, or with strengthened woven asbestos packing. For small pipes and in feed lines bends instead of expansion joints are introduced to allow for the movement of pipes. By use of bends no danger of leakage is introduced and there is a saving of weight. Expansion joints will generally be found only on the larger piping.

*Packing for Expansion Joints.*—This is usually metallic, reinforced by asbestos woven rings. Specially prepared asbestos woven rings are also used without metallic packing.

*Lead Piping.*—Feed pipes are made of copper with composition flanges, steel bolts and composition nuts, and is packed with copper gaskets, wire gauze and red lead, or with thin wire insertion packing.

The auxiliary feed suction pipes take their suction from the feed tank connecting pipe, or directly from feed tank, and lead forward to the boiler compartments. They have suction connections to all the auxiliary feed pumps in the boiler rooms.

The main-feed suction pipe takes its suction from the cross-connecting pipe of the feed tank or from the feed tank direct, and leads to the suction of main feed pump.

Feed discharge pipes lead from discharge side of main feed pump (through feed heater if fitted on suction side of pump) and then to the boiler compartment, having branches to discharge to boilers on its own side of the ship and a cross connection to the opposite side. Gate valves are fitted to cut out portions of piping not in use.

On many vessels there is only one main feed line which supplies both sides.

The auxiliary feed pumps discharge into a fore-and-aft delivery pipe having branches so that all boilers on that side of the ship can be fed.

The lead of piping differs for nearly every vessel, both main and auxiliary feed systems are, however, installed in nearly all cases.

The cut-out valves in the feed-line main are usually gate valves, to give a clear opening and reduce friction. The branches to the boilers have either stop valves or gate valves.

Feed pipes are fitted with bends to allow for expansion. Feed pipes should be covered with non-conducting material and are, as much as possible, carried above the floor plates.

*Bottom and Surface Blow Pipes.*—The bottom and surface blows of boilers are connected with a system of piping which connects to the overboard discharge valve in its own or adjacent compartment. This system of piping is connected to the fresh-water manifold of the auxiliary feed pump in the boiler compartment. This connection is for use in pumping out boilers.

In the latest vessels contracted for the auxiliary feed pumps have no salt-water connections whatever. This is to effectually guard against the possibility of salt entering the boiler feed.

*Hotwell and Fresh-Water Pumping System.*—Where hotwell pumps are fitted they have a suction to the cross-connection pipes between the feed tanks and to a cross-connection between the two air-suction pipes, to suctions on ship's side for taking on board fresh water, and to reserve tanks for the purpose of distributing fresh water. These pipes are of copper, flanges faced and grooved, and packed with approved rubber packing.

The hotwell pump has discharge piping to the reserve tanks by means of a combination manifold where one pipe can be used for either suction or discharge.

The hotwell pump discharge to feed pump suction is arranged so as to pump through or by-pass the heater, if suction heater is fitted, and then to feed suction pipe. Where pressure heaters are fitted, the hotwell pump simply discharges into the feed suction, its object being to enable the main feed pump to obtain a good suction. A great many vessels have no hotwell pump, but there is usually a fresh-water pump for handling fresh water in reserve tanks and for pumping fresh water on board.

The piping to and from the reserve-feed tanks in the latest vessels is of wrought iron or steel, galvanized, the same as bilge and drainage piping.

*Air-Pump Piping.*—This consists of (1) a suction pipe from condenser to air pump. (2) A discharge from air pump to feed and filter tank, and a connection running across the ship, connecting the two air-pump suction pipes. By means of this cross-connection either air pump can work on either condenser. This cross pipe also has connections to the hotwell pump or to some of the feed pumps, so that these pumps can pump direct from the condenser. Such a connection would enable the condenser to be used although the air pump should be broken down.

The exact arrangement of air-pump piping can be understood only by an examination of the piping plans for a vessel.

*Salt-Water Suction and Discharge Piping.*—Pipes for circulating water for main, auxiliary and dynamo condensers.

These pipes are of copper, have composition flanges packed with rubber packing.

Zinc protectors are fitted in standard zinc boxes for preventing corrosion of the pipes. Joints in such piping are made in accordance with Standard No. 86, issued by the Navy Department.

### DRAINAGE SYSTEMS.

*Drainage Piping.*—The drainage piping of large vessels consists of a main and a secondary drain with their suctions, a double-bottom pumping system for the inner-bottom compartments other than the reserve feed tanks, the connections from these systems to the pumps, and the discharge pipes from the pumps overboard.

*Main Drain.*—The main drain is a pipe made of steel; for large vessels it is about fifteen inches in diameter. This drain extends throughout the machinery spaces and has a suction in each boiler and engine compartment. Each suction valve is fitted with gear for operating from above the protective deck.

The main drain has pumping connections to the bilge pumps in the engine rooms and to the auxiliary feed pumps in the fire rooms, on all but latest vessels, those contracted for after 1904. These connections are either direct or through the drainage manifold, which in late vessels is separate from the engineering manifolds at pumps, having connections to main drain, secondary drain and double bottoms.

The main drain also has connections to each main circulating pump in the engine room.

On the latest vessels the connections from the drain to fireroom, fire and bilge pumps have been omitted.

*Secondary Drain.*—This is a pipe varying in diameter from five to seven inches, and is located along the center line of the ship on the side opposite from the main drain. This drain is connected, in forward boiler room, to a manifold which has valves controlling the suctions to the forward parts of the vessel outside of the engine-room compartments. In the after part of the engine room it connects to a similar manifold which

controls the suctions to the after compartments of the vessel. The secondary drain has suctions in each engine and boiler compartment with valves worked from above the floor plates, and on many vessels arranged to be worked from deck as well.

The secondary drain has pumping connections to the fire and bilge pumps and to the auxiliary feed pumps. These connections are either direct to the pumps or through the drainage manifolds. In the latest vessels contracted for after 1904 auxiliary feed pumps are not so connected.

*Independent Bilge Suctions.*—The bilge pumps in engine rooms have an independent bilge suction pipe, which has suctions to engine bilge, crank shaft, and, in latest practice, to shaft alley. Additional branch suctions are sometimes fitted to this pipe for the purpose of pumping out pockets difficult to keep dry.

The auxiliary feed pumps or boiler-room fire and bilge pumps have an independent bilge suction to the bilges of their own boiler compartments.

Strainers are fitted in all suction pipes for the purpose of collecting dirt from the bilge and preventing it from clogging pipes and pumps.

*Valves and Manifolds.*—The valves in manifolds at pumps are usually check valves arranged so that they can be raised off their seats by an extreme movement of the valve spindle, usually called stop lift check valves.

In order to pump a compartment through the secondary drain it is necessary to open the suction valve for the compartment, the valve drainage manifold which controls secondary drain suction, and the stop valve separating drainage manifold from the pump manifold.

*Double-Bottom Piping.*—The double bottoms are connected to a double-bottom main, which is arranged so that the fire and bilge pumps or auxiliary feed pumps can pump on them either by a direct connection to the pump manifold or through the drainage manifold. Valves controlling the suctions to the

compartments are located above each compartment and are arranged to be operated from above the floor plates.

On other vessels the system is arranged so that independent pipes, one from each compartment, lead to double bottom manifolds located in boiler and engine rooms.

The system of double-bottom piping with its manifolds and valves is under the cognizance of the Bureau of Construction and Repair.

*Water-Service Piping.*—The water-service piping consists of brass-piping for conveying the water to various engine and thrust bearings.

On some vessels the water service takes its water from the discharge of main circulating pump, and the water after leaving the bearing or guide, instead of going to the bilge is allowed to discharge to main circulating-pump suction, thus avoiding a very large amount of water in the bilges and crank pits.

*Flushing System.*—Material of pipe, copper. This system consists of a main supplied by a connection from the distiller circulating pump and also usually by a connection from the fire main. This pipe has branches supplying water to water closets, urinals, wash rooms, shower baths, laundry, pantry and galleys. Relief valves are fitted to prevent an excessive pressure coming upon the pipe.

This pipe, from a flange located near the distillers, is under the cognizance of the Bureau of Construction and Repair.

*Fire Main.*—Copper.—This system, on large vessels, consists of two large mains, one on each side of vessel, directly underneath the protective deck within the machinery spaces. These two systems are cross connected and are connected by pump risers with the fire and bilge pumps in engine rooms, the fire and bilge or auxiliary feed pumps in boiler rooms and, in some vessels, with the distiller circulating pumps.

The risers from the pump are fitted with cut-out valves near the main. From the main on each side risers are taken, usually through some of the machinery hatches, and have plugs and short branches on the various decks.

Each riser is fitted with a cut-out valve below the protective deck close to the main. These valves are arranged to be worked from above the protective decks. By this arrangement it is possible to cut out any riser when damaged, without impairing the rest of the fire main.

The fire main has connections for flooding the magazines above the lower platform. There are also connections to each ash chute for flushing same. These last should more properly be connected with flushing system.

Plugs are arranged so that any part of vessel can be reached with a fifty-foot hose from two plugs.

All valves in fire main are composition gate valves. Chapman valves are largely used. The relief valves on fire main are set at one hundred pounds pressure.

Zinc boxes are fitted in the fire main to prevent corrosion.

The principal difficulty experienced with fire mains is the corrosion of pipes due to the action of salt water, and leaky valves. Of late most gate valves are fitted with removable seats which can be taken out and faced off in a lathe when the seat becomes rough.

All fire-main plugs are either 2½-inch or 1½-inch Navy standard.

The fire main and all risers from it are under the cognizance of the Bureau of Construction and Repair. The risers from the steam pumps to the fire main are under the cognizance of the Bureau of Steam Engineering.

The division of cognizance between the two Bureaus is at the flange on the main between the riser and the main.

### REMARKS ON ERECTING PIPING ON BOARD SHIP.

*Steam Piping.*—A great deal of the trouble experienced with steam piping is due to want of alignment. This want of alignment operates to throw excessive strains on the flanges of stop valves, anchorages, separators and expansion joints. These strains are brought about by reason of the flanges being brought together by forcing on the connecting bolts instead of the joints coming fair without this outside assistance. Any

joint that requires outside pressure to make the parts come together will cause trouble. When the flanges do not come together fairly they should be taken down and refaced, and, if necessary, a thin steel distance piece put in to make the required length. When erecting heavy pipes, every length should be placed in position and properly supported and aligned in its own brackets and hangers, before being permanently secured. It will usually be found that various lengths will have to be altered slightly before proper alignment is obtained.

Expansion and contraction due to change in temperature, to vibration and to slight movement of the structure of the vessel must be properly allowed for. To this cause most leakage in joints is due. The positions of anchorages, bends, valves and branch connections will materially affect the ability of the piping to accommodate itself to the changes.

When certain joints are continually leaking, the connections should be carefully studied; often some slight alteration can be made in the anchorage, connections, hangers or lead of pipe that will allow for the necessary movement and prevent the strain which causes the leak coming on the joint.

Vibration is a prolific cause of leakage, especially in small steam piping. Vibration of pipes can often be largely stopped by placing bands or guys on the pipes that will stop the vibrating movement but which will not prevent expansion or contraction due to temperature or to regular movement of the vessel. Often the pipe can be prevented from vibrating by taking a turn of wire around it and securing the wire to some part of the ship's structure.

*Position for Drainage.*—Steam pipes should be erected so that they will naturally drain themselves and so that pockets, where condensed water may accumulate, may be avoided. The danger from the accumulation of water is two-fold: (1) water ram; (2) injury to packing. The pipe lines should be run so that the water of condensation will drain either back to the boilers or to the separator. Where the piping is long and complicated, drains should be fitted at frequent intervals.

Pockets where water collects are often formed by stop valves

being placed so that their bodies form a water trap. An example is shown in cuts (Lunkenheimer Co.'s catalogue) Fig. 1. In the first figure the arrangement permits the accu-

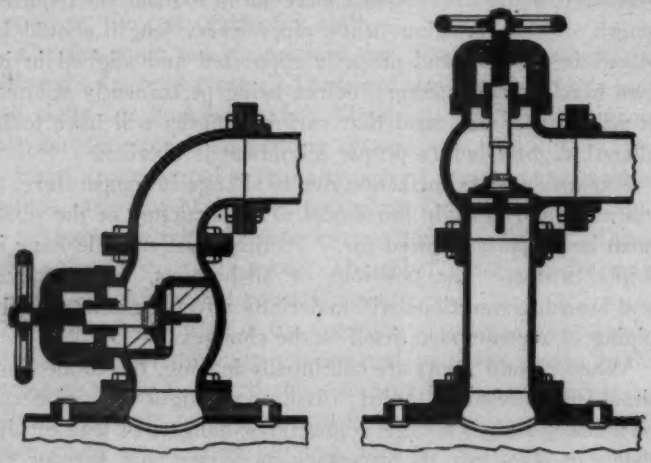


Figure 1.

mulation of condensed water above the valve when it is closed, and by careless opening water hammer may result. In the second figure the forming of a water pocket is avoided. In any case where such pockets are unavoidable a drain should be fitted, and this drain should be open before the large valve is opened.

*Care in Fitting.*—The greatest care should be exercised in fitting pipes to see that all dirt, grease, parts of gaskets, scale or little pieces of metal are not left in the piping; since this foreign matter is liable to get into the valves and cause them to leak. In smearing flanges with grease care should be taken that this does not get into the piping and valve castings, since it will be carried to the bearing parts of the valve and there, owing to its sticky nature, it will hold grit and scale on the seats and cause them to become scored.

*Corrosion of Piping.*—Internal pitting, due to air, is liable to be met with, and the interior of pipes should occasionally

be examined to see if any is present. External corrosion is also liable to result from the combined action of the heat and moisture on asbestos pipe covering, causing pitting. This outside corrosion can be guarded against by giving the pipe a good coat of graphite paint before the covering is put on.

*Repairing Leaks.*—Leaks in copper piping are permanently repaired by rebrazing the seam or by brazing on a patch. To braze on a patch, clean the metal carefully with file, emery cloth and hydrochloric acid. Cut out a piece of copper of suitable thickness and shape it carefully to the pipe, cleaning thoroughly the surface next to the pipe. The patching piece is securely wired in place. The pipe is then heated in a forge with a charcoal or coke fire. Spelter or hard solder, with borax as a flux, is placed over the hole on the inside and the whole heated, the pipe is moved and turned about to keep the brazing matter from running away from the patch. As the brazing mixture melts, it runs betwen patch and surface of pipes and makes a joint between the two. If the hole is very small, the brazing mixture may have to be put on the outside and caused to run in from one side of the patch. Great care must be exercised to prevent the pipe from burning. By the use of loam the heat may be directed to any one position and protect the other parts from injury.

A patch may be welded, riveted or bolted on a steel pipe. If the leak is a small one on a thick pipe, the hole may be rounded out and a rivet put in from the inside and hammered over from the outside. Or the hole may be tapped out and a small plug screwed in and riveted over on the outside. It is, however, very difficult to make a permanent repair with the pipe in place, though often there is not sufficient time to take pipes down, and a temporary measure must be adopted.

*Some Methods of Temporary Repair.*—Place a putty made of red lead and oil, sometimes mixed with pieces of hemp to give strength, over the leak, wrap with canvas, and then serve the pipe with marline. Or place a piece of packing over the putty and then serve with wire. Another way is to put on the putty and then serve the pipe with wire, and solder the wire

on as it is being served. Clamps made of iron or brass and drawn up with bolts are often useful in holding the patch over the leak. A very secure patch can be made by shaping a piece of copper to the leak, then put a piece of soft packing coated with red lead between the pipe and copper and draw the piece of copper up with several bolted clamps. Pine plugs driven into holes form a ready means of stopping a leak in low-pressure water piping. After the plug is driven, the moisture will cause it to swell and continue to make it tighter. Pin holes may be closed by the use of soft solder. Portland and smooth-on cements are also very useful in repairing leaks. Smooth-on cement is especially good for cracks in metal piping or casting.

Brass and copper piping in bilges should be kept well covered with paint. If there are bare places and the bilge water is brought into contact, galvanic action is liable to be set up.

Copper water piping is peculiarly liable to electric corrosive action. The use of zincs acts in some manner as a preventative, but where there is a continual flow of salt water it appears to be impossible to prevent the corrosive action. Tinning the pipes also acts as a preventative to some extent, but it does not stop the action. In order that the various sections of piping may not be insulated from each other by rubber gaskets at flanges, the flanges can be connected by short pieces of copper.

## DRAINS AND TRAPS.

Places where condensed steam can accumulate are provided with drain pipes with or without traps for conducting such water to the feed tanks or condensers.

The parts usually fitted with drains are as in the accompanying table.

MACHINERY DRAINS.

| Parts drained. | Drains through— | Drains to— |
|---|---|---|
| Main steam separators.... | Approved automatic "float trap" with by-pass. | Main condenser, feed tank near bottom. |
| Dynamo steam separators. | Do. | Dynamo condenser. |
| Exhaust to low-pressure receiver (separator if directed). | Do. | Main condenser. |

| Parts drained. | Drains through— | Drains to— |
|---|---|---|
| Dynamo exhaust pipes (separator if directed). | Trap with by-pass and pumps (if directed). | Exhaust to dyuamo condenser, above valve at condenser. |
| Aux. steam separator, steam pipes and valves. | Approved automatic "float trap" with by-pass. | Main condenser, aux. con., feed tank near bottom. |
| Whistle pipe and separator. | Do. | Feed tank near bottom. |
| Low-pressure jacket drain (¾-inch diameter). | Approved automatic "float trap" with blow through, or "expansion trap." | Lower part of feed tank. |
| High-pres. evap. coils..... | Do. | Feed tank, main and aux. cond. |
| Low-pres. evap. coils..... | Do. | Same, with branch to dis. fresh-water pump suction. |
| Heater drains (each man.) | Do. | Feed tank, main and aux. cond. |
| Galley steam drains..... | Do. | Feed tank, aux. cond. |
| Cylinder drains, main engine. | No trap, unite in pipe. | Top main cond. and to bilge. |
| Cylinder drains, aux. eng. | No trap..... | As approved. |
| Cylind. drains, dyn. eng. | No trap..... | Dyn. cond. above valve. |
| Cylinder relief valves..... | No trap. Drain pipes. | Bilge. |
| Valve-chest drains..... | Do. | Main cond. and bilge. |
| Feed-water heaters..... | Trap if required..... | Feed tank, main and aux. cond. |
| Where hot water passes... | Float traps *must* be used. | As approved. |
| Where warm water passes. | Float or expansion traps. | Do. |
| Bath heaters..... ..... | No trap..... | Most convenient aux. exhaust in continuous operation. |

Drain pipes are of copper, and are fitted with unions where necessary so that the pipes can be readily disconnected for overhauling.

Steam traps are now fitted of many different kinds. They are of two general types: (1) the float trap, (2) the expansion trap.

The following extracts from an article by Lieutenant R. T. Winston, U. S. Navy, show the results of recent experience with steam traps in the U. S. Navy.

## STEAM TRAPS.

"*Types of Traps.*—The open-bucket float type, though bulky and somewhat affected by the ship's motion in a seaway, has given the most general satisfaction. It will take care of a sudden gush of water and requires no adjustment for varying pressures and temperatures.

"The hollow-ball float type has given some trouble on account of the ball corroding through, getting punctured or becoming detached. This type should give satisfaction if proper provision has been made to insure watertightness of the float and if the float is securely attached to its lever.

"The expansion type of trap is superior to the float type in that it is not bulky, has few parts and lasts well. It does not work well where there are wide variations in the temperature or in the amount of water to be handled. Under such conditions trouble has been experienced with the frequent adjustments, irregular working of the trap and the leakage of steam.

"The following traps are largely used in the Navy: (float type) Dinkel, Nason, McKellar and Kieley; (expansion type) Geipel.

"*Requirements of a Good Trap.*—The best trap is the one that will discharge the water which collects without wasting steam and at the same time requires little attention. Other qualities to be considered are durability, simplicity, facility of overhauling, weight, size and cost.

"It is better to have the drain valve of a trap at the top of the chamber rather than at the bottom, where sediment collects. It is also an advantage to have valves outside the float chamber, where they may be cleaned and overhauled without breaking a joint.

"The bonnet of a float trap should be secured with studs, or if through bolts are used, the heads should be so fitted as to prevent turning. The facility for overhauling might be still further increased by the use of hinged bolts.

"The piping for all traps should be fitted with union couplings to facilitate the removal of trap for examination or re-

pair. In case of an expansion trap, the discharge should be fitted with a by-pass to the bilge, by means of which it could be determined whether the trap was working properly.

"*Traps for Special Use.*—Where the quantity of water is subject to sudden variations, as in steam pipe and separator drains, the float type should be used. Where there is a slow, regular and continuous condensation at a practically constant temperature, the expansion type is satisfactory and often desirable.

"For cylinder jackets of main engines an arrangement similar to that on vessels of recent designs seems best; *i. e.*, steam goes from the H.P. jacket to the I.P. jacket through a reducing valve from the I.P. jacket to the L.P. jacket, through another reducing valve, and then drains through the I.P. jacket trap; one trap taking care of the water for the whole system.

"The following easily improvised substitute for a jacket trap has been used with success: A small cast cylinder, fitted with a drain valve and a gauge glass, is placed in the jacket drain-pipe line. When in operation, the drain valve is opened just enough to keep the water in gauge glass at a fixed height, the whole arrangement being near the starting platform, and readily seen.

"For steam radiators the bucket type generally gives the best results. Expansion traps when used should be placed close to the radiators, and each trap should not drain more than two or three coils; they have been found to give considerable trouble when required to drain more than one heating circuit.

"For evaporators and feed heaters bucket traps have been extensively used. It is probable that an expansion trap, carefully installed, would work efficiently on evaporator coils.

"Drains for feed-water heaters when discharging to condensers do not require traps, but if the heater drains discharge to the feed tank traps may be necessary.

"For steam separators and steam lines bucket traps must be used.

"*Location of Traps.*—A trap must be located below the lowest part of the vessel or pipe to be drained, and, if practicable, above the level of the tank into which it discharges, in order to prevent water backing up when the trap is not in operation. This applies particularly in the case of the expansion trap, which has given trouble in discharging against a head of water. Under certain conditions it may be necessary to fit a non-return valve in the discharge line.

"All traps, and particularly those which will need frequent overhauling, should be so placed as to be easily overhauled and examined. If a trap cannot be installed where it is fairly accessible for overhauling it should be omitted and a drain valve fitted instead.

"*Operation and Overhauling.*—Many traps are of no value on account of lack of care and attention.

"A float trap can be heard 'dumping' when in order, and may work satisfactorily for months without overhauling. Whenever the sound of dumping is not heard at intervals the trap should be examined at once. Less trouble is experienced with a large trap than a small one, as in the latter case valves are more easily clogged, thus causing a failure to discharge, or if not entirely stopped will permit a leakage of steam. This is particularly the case where there is likely to be sediment in the water.

"While experience is necessary to judge in each particular case the period a trap may be left without examination, it may be said in general that a large trap should never go more than three months or a small trap more than two months without examination and cleaning.

"By opening the expansion-trap discharge by-pass to bilge it may be seen whether the trap discharges water properly, and if it leaks steam. The trap should be tested frequently when in use and adjusted and cleaned out if necessary."

*Draining Steam Lines.*—Steam lines and separators are fitted with drains usually led to traps, the discharge from the trap being led to the feed tank or the auxiliary condenser.

On some vessels main separators are also drained by leading

a pipe from the bottom of the separator for operating some reciprocating pump, such as a hot-well pump. Dynamo separators are sometimes drained by leading a pipe from bottom for operating dynamo condenser pumps. By this system the separators are being drained continuously.

*Draining Jackets.*—In order that steam jackets may work efficiently they must be kept constantly drained. If jackets fill with water they do not impart any heat to the steam in the cylinder.

In the Navy there are two different systems for draining jackets. On late vessels, steam first enters the H.P. jacket, the discharge leads through a reducing valve to the I.P. jacket, then through another reducing valve to the L.P. jacket. The discharge from the L.P. jacket leads to a trap. The reducing valves placed between the jackets can be set to regulate the pressure in each of the jackets. Sometimes additional drain cocks are fitted at the bottom of each cylinder jacket to allow any water condensed in the jacket to be drawn off.

The other system is to have each jacket have its own independent steam connection, reducing valve and trap.

While jackets are being used the traps should be occasionally by-passed to ensure that water is drawn off.

*Cylinder Drains.*—The cylinders and valve chest of the main engines are fitted with drain cocks at the bottom. These cocks are arranged so as to be operated by shafts and levers from the working platform. One lever being arranged to move all the cocks of each cylinder and its valve chest.

The drain cocks are high-pressure packed cocks.

The discharge from cylinder drains leads to a pipe which leads to condenser, and is usually fitted with branch to bilge.

The drains are led to the condenser to ensure thorough draining. To avoid blowing through to the condenser it is most important to see that the drain cocks are tight.

Particular attention must also be paid to see that the valves in branches to the bilge are absolutely tight.

Cylinder drains of auxiliary engines are either led to traps

or to bilge. The large auxiliaries, such as dynamo engines and circulating pumps, usually have their drains led to traps. For the purpose of saving fresh water it would seem advisable to lead the drains of the various auxiliaries now going to the bilge, to the auxiliray exhaust. This has been done on some vessels.

*Heater Drains.*—Heater drains are led to traps which discharge to the feed tank or to the auxiliary condenser. In order to ensure pipes being thoroughly drained these traps should be occasionally by-passed. If heaters are not properly drained they fill up with water and there is no proper heating effect. Drains from the galley and pantries are led to traps.

Bath-heater drains are led to the auxiliary exhaust line. At first these drains were led to traps, but as there was not a steady drain the heaters did not work well. When connected to auxiliary exhaust there is always a thorough draining.

The principal repairs to drains consist in tightening up on leaky joints, nipples and unions, repairing split pipes, overhauling traps and grinding in and packing valves.

The principal cause for leaks is the accumulation of water in the pipes.

Valves are generally caused to leak by having their seats scored from dirt or scale in the piping, or by the valve disc and seat corroding from the action of salt, acid or alkali in the drain water.

## BLOWERS AND BLOWER ENGINES.

Blowers are installed on board ship for purposes of furnishing forced draft for the boiler plant and for ventilation.

The system of forced draft almost exclusively installed, is the closed-fireroom system. On some small vessels and on the armored cruisers *California* and *South Dakota* the closed ash-pit system is installed.

The blowers are installed in the firerooms, generally suspended from the protective deck or they are located on the protective or splinter deck above the boiler rooms, where they have a more substantial support and are not so liable to shock and vibration.

When they are above the boiler rooms the engines can be much easier kept clean, they are more accessible for overhauling and attendance, and they are not required to work in such a high temperature. They can also be repaired without interfering with the operation of boilers.

Two blowers are usually fitted for each boiler compartment, so that if one should break down the other will be available. In order that the pressure may not be lost through the opening to the disabled blower, air-tight doors or shutters are fitted on the blower ducts.

Types of fans adaptable for naval service are as follows.—

*Peripheral-Discharge, Straight-blade, Centrifugal Fan.*—This is the type most largely encountered, and is specifically suited to the conditions for producing forced draft on naval vessels. The hub is of cast iron and fitted to the steel shaft. It has steel T arms rigidly cast into place; in other types the hub and T arms are cast in one. The steel plates are riveted to the arms, and the plates, in turn, are bolted to the conical side plates

*Curved-Blade Peripheral-Discharge Fan.*—For heating and ventilating fans the blades are sometimes turned backward to secure an easier escape of the air and to reduce the noise of the fan.

*Cone Ventilating Wheel.*—This type secures very great efficiency and is especially suited to places where air is drawn from one compartment without ducts to an adjoining one. It is usually installed without a casing. At the center of the wheel, forming its hub, is a conoidal casting with its apex toward the inlet side of the wheel, so that the entering air is gradually deflected in its course. By this means all unnecessary friction and loss of heat, due to change of direction, are avoided.

Attached to the circumference of the casting is the steel back plate of the wheel which carries the numerous curved blades. This back plate is stiffened by T steel arms radiating from an auxiliary hub. This type is used on torpedo boats for forced draft.

*Disc Wheels.*—For moving large volumes of air under low

pressure with a minimum expenditure of power, disc wheels are very efficient. They are especially applicable to exhaust ventilation. The fan consists of a hub to which are cast or otherwise secured radial arms to which the steel plate blades are attached. The blades, acting as inclined planes, force the air through and beyond in a direction parallel to the shaft.

Fans having their blades curved to a regular pitch, like a propeller, are also used. An increase in the number of blades does not add to the capacity of the fan, but secures smoother working.

*The Sirocco Blower.*—This type of fan is, like the others, based on centrifugal action, but in the blower the blades are arranged in a different way. The blades are long and narrow, and curved forward in the direction of rotation and mounted parallel to the shaft. The length of blades is about ⅗ of the diameter, and the height, radially, is about $\frac{1}{18}$ the diameter of the fan. The blades are set closely together and are riveted to an iron ring at the back, which is attached to a cast-iron conical hub, the front ends of blades being riveted to an iron ring. The suction is at the center and discharge at periphery, as on other centrifugal types.

The Sirocco blower is a late development, and an increase in efficiency of about ten per cent. over the ordinary type is claimed for it.

The ventilating blowers on board naval vessels are now operated entirely by electric motors and require the usual care of such electric apparatus. The fans are usually peripheral discharge wheels with curved blades.

*Forced-Draft Blower Engines.*—Forced-draft blowers are operated by fast moving steam engines. They are usually two-cylinder simple or two-cylinder compound engines. On torpedo boats, yachts and small vessels horizontal engines are used. Turbine engines may also be used. The speed of these reciprocating engines is 250 to 700 revolutions per minute. On the latest vessels forced-draft blowers are to be electrically driven.

Blowers and blower engines are usually of special make. Forbes, Sturtevant, and Buffalo Forge Co. are makes very generally used.

One of the most important matters in installing blower engines is to secure sufficiently rigid supports to check vibrations at high speed. Supports to suspended engines are usually too light, and they are not sufficiently rigid. These faults can often be remedied by installing additional braces.

*Operation.*—The principal thing to look out for is to keep a proper supply of oil. Blowers are usually fitted with closed automatic sight-feed oil boxes, and some have forced lubrication, similar to that of the latest dynamo engines. To maintain a certain air pressure the speed necessary will depend in a large measure on the tightness of the forced-draft doors. If there is much leakage the blower engines must be run faster.

The speed at which the blower is to be run is regulated by the water tender in charge of the fireroom, who is governed by the air pressure that he wishes to maintain. On vessels where blowers are above the protective deck the admission of steam is often controlled from the fireroom by means of an extension stem from the blower branch steam pipe.

*Care and Overhauling.*—Blower engines require periodically a general adjustment of working parts and an examination of cylinders and valves. With well designed and well balanced engines little trouble is met with.

One of the principal troubles with blower engines is dirt and grit, dust, etc., getting into some of the bearings. Special care should be taken to see that the doors of casings, oil service, etc., is absolutely dust tight. The space surrounding the blowers should be kept clear of dust especially at the times that the engines are being overhauled. Additional dust guards can often be fitted over bearings and oil service.

In order to insure blowers being ready they should be tried at least once a month under steam. Forced-draft doors, etc., must be frequently overhauled, as they often warp out of shape from heat.

## ASH HOISTS.

Ashes are usually disposed of by hoisting them to the main or gun deck and dumping them in the ash chute.

Fireroom ventilators are used for the hoists, and rails are fitted for the purpose of guiding the ash buckets. The engines are usually located in the fireroom hatch at the level of the gun deck. One engine is employed for a hoist at each side. The engine is put in gear with either side by means of a shifting clutch. A general type of ash hoisting engine is that shown in Fig. 2.

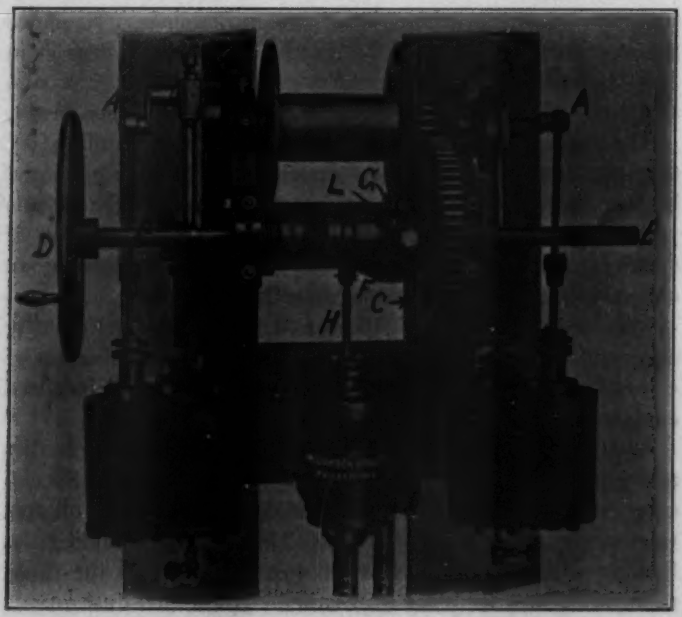



Fig. 2.

*Operation.*—Steam should be turned on slowly and cylinders drained. The control wheel should be turned uniformly and not by jerks. Control wheel should not be suddenly reversed. Great care is to be taken that the change clutch is properly in gear, and that it is in gear on only one side.

The detail method of operation is as follows: AA, are single eccentric cranks, which operate the main valve on each cylinder. B, is a gear wheel fixed to the drum and gearing into a spur wheel C, cast on a sleeve, L, with an internal thread to correspond to the external thread on shaft E. A groove is cut in the sleeve fitted with a loose collar, G, which, through a bell-crank lever, F, moves the reversing valve by means of the valve stem H, when spur wheel C moves to the right or left.

Turning the starting wheel, D, to the right, the spur wheel, C, moves to the left, the differential valve moves downward and the engine turns, moving the drum shaft to the left; the spur wheel, C, will then have a right-handed motion, pushing the sleeve to the right, and closing the differential valve, with the result that if the hand wheel is stopped the engine stops, or if the hand wheel is turned in the opposite direction a reverse movement is given.

The thread shown on the shaft carries a nut, J, which is prevented from turning, but has a certain lateral motion, between the safety stops, to give a proper amount of hoist. On bringing up on the stops the engine is stopped. This prevents overwinding and the breaking of cable, and stops the ash bucket as it reaches the fireroom floor. The stops can be adjusted to the desired hoist.

*To Overhaul.*—It often happens that parts of these engines are out of line. In some cases the stuffing boxes when packed tight may throw valve stems to one side. Parts of clutches are often made of cast iron, and sometimes break from jar. When made of composition they will stand wear and jar much better.

The wire hoisting cable should be kept clear of paint and occasionally wiped over with graphite and tallow.

Cylinders and valve chests should be periodically overhauled and coated with graphite. When drains of ash hoists lead to open air special care should be taken to see that they are closed while engine is standing idle.

*Electric Ash Hoist.*—This type of ash hoist has been used in some foreign vessels. The electric hoist is heavier and more

costly than the steam engine, and there are other disadvantages to cause its non-adoption for general service.

Ash hoists are located near boiler rooms so that steam leads are always short and direct.

The lift ash hoist, consisting of a long steam cylinder whose piston operates a multiple pulley, is used on some vessels, and these are often met with in the merchant service. The noise encountered with the usual type of reciprocating engine is avoided and the space occupied is very small.

*Ash Ejectors.*—Some naval vessels, especially torpedo boats, destroyers, and scout cruisers, which are likely to be under heavy forced draft for long periods, are fitted with ash ejectors for removing ashes from the firerooms. A connecting pipe leads through side of the ship several feet above the water line. The connection at the bottom of the hopper is led to the discharge of a pump.

The operation is as follows: The lid of the hopper is closed and the jet cock and drain cock are closed. First drain the water from the discharge pipe by opening the drain cock, and start pump. When a good pressure has been obtained, open the jet cock quickly. The water issues from the jet nozzle at a high velocity and discharges at the upper end of the pipe. It creates a suction in the hopper, and if this is now opened and the ashes shoveled in they will be sucked in and then carried up with the water and ejected from the ship's side. When all ashes are in, the hopper is secured and pump stopped.

The base of hoppers is fitted with a grating to prevent large lumps coming in and clogging the pipe.

Difficulties with ejectors arise from opening the hopper before a proper jet suction is secured, or by stopping or slowing the pump before closing the hopper. If this is done the water will back into the fireroom.

The pump for operating must be sufficiently large to maintain a constant pressure at the jet. Duplex pumps are considered more desirable for this purpose, but simplex pumps are also used. The connection from the pump should be short and direct, and the pump should be in the same compartment

as the ejector. Where ejectors are less than 4-inch diameter, considerable trouble is experienced by pipes clogging. The bent part of pipe is subject to considerable wear from the suction of ashes and clinkers. This is often made up with a specially thick cast-iron piece that can be renewed when worn.

## TELEGRAPHS AND REVOLUTION INDICATORS.

Mechanical telegraphs for the purpose of transmitting orders for operating the engines from bridge to engine room are now all made to conform to a certain standard.

The principal attention that these devices requires is occasional oiling of pulleys and adjustment of the length of chain. In warm weather, or where the leads are in proximity to boilers, the heat will cause the chains to lengthen. This is especially so on vessels having a long lead.

This slack is taken up by turnbuckles placed at intervals. The spiral springs which control the bell clapper sometimes become weak and have to be renewed.

Mechanical telegraphs for transmitting orders from engine room to boiler rooms are also fitted. These are arranged so that all the dials are operated when any one of them is moved.

An electric revolution regulator to signal to the engine room to go from one to four revolutions slower or faster is also fitted. There is a light for each number on the dial, and an electric bell which rings when the contact lever is moved.

Electric speed indicators are fitted on some vessels which show the number of revolutions at which the engine is moving.

*Electric Revolution Tell Tales* are fitted for each shaft. A contact maker operated by a cam on the shaft, and which makes one contact at every revolution, is located in the shaft alley. This is connected with a case which has mounted on it two small index hands which move at every contact. The circuit is wired so that the ahead hand moves when engine is moving in the go-ahead direction, and the backing hand moves when backing. This is usually accomplished by a cut-out on the reversing shaft.

A mechanical revolution indicator is fitted in each engine

room, placed so as to be readily seen from the working platform. These are worked from the engines by positive movements. The dials are graduated to 100 revolutions, each graduation indicating one revolution of the engines.

The object of the above instrument is to actually demonstrate at a glance the revolutions of both the starboard and port engines, the red hand indicating the speed of the port and the green hand that of the starboard.

Provision is made for stopping either pointer, so that the engines may be quickly regulated with the aid of the indicator.

### GENERAL WORKSHOP.

The general workshop on large vessels contains the following machine tools:

Large lathe;
Small tool-room lathe;
Shaper;
Milling machine;
Drill press;
Sensitive drill.

On the smaller vessels the milling machine and sensitive drill are omitted.

The following are the specifications for the machine tools for the latest battleships.

### MACHINE TOOLS.

There will be provided and installed in the general workshop the following machine tools, viz:

One screw-cutting, back geared, extension gap lathe, to swing at least 28 inches over the upper and 48 inches over the lower ways, with not less than ten feet between the centers, when extended.

To have hollow spindle, compound rest, steady and follow rests, power cross feed, taper attachment, countershaft, 2 face plates, 1 large and one small chuck, one drill chuck and a complete set of at least 16 lathe tools and 7 lathe dogs.

One screw-cutting, back-geared tool-room lathe to swing

at least 14 inches over the ways and not less than 4 feet between the centers.

To have quick-change feed gear, power cross feed, hollow spindle, taper attachment, oil can, one large and one small face plate, counter shaft, one large and one small chuck and drill chuck, drawing-in attachment, with complete set of chucks, a set of at least 12 lathe tools and 6 lathe dogs.

One column tool-room shaper of at least 15-inch stroke and not less than 15-inch traverse; to have automatic stop, adjustable table, and graduated swivel vise with jaws for taper work, 24-inch graduated index center and a set of at least 12 shaper tools.

One upright drill, to drill up to 1½ inches, to have at least 14 inches from edge of work, to have not less than 14 inches of traverse of spindle, to be fitted for No. 4 Morse taper, with requisite number of sockets.

To have a complete set of twist drills from ¼ to ⅝ inch by 32ds, and from $\frac{1}{16}$ to 1½ inches by 16ths. To have automatic and hand feed, sliding head, counterbalanced spindle, circular table, revolvable by gear and adjustable vertically by gear, automatic stop, tapping attachment, countershaft, and a small drill chuck fitted.

One 16-inch sensitive drill, to have a counterbalanced spindle fitted for No. 1 Morse taper, sliding head; table to have vertical adjustable movement, to drill holes up to ⅝ inch, with drill chuck and complete set of drills from $\frac{1}{16}$ to ⅝ inch by 32ds.

One universal milling machine with overhanging arm; to have at least 18-inch longitudinal feed of table, 13-inch vertical movement, and 4½-inch traverse. Spindle to be fitted for No. 9 B. & S. taper. To have automatic cross feed, universal chuck, arbor, index, swivel, vise, spiral cutting attachment, countershaft, 3 milling cutters, 2 side millers, 6 metal slit saws, 3 angular cutters, 4 end mills and 2 collets.

One combined hand punch and shears with 6-inch shear blades, to cut ¾-inch round iron, shear ⅜-inch steel plate, and punch ⅜-inch holes in ⅜-inch mild-steel plates 4 inches from edge.

One double emery grinder on column, with carborundum wheels, 12-inch diameter by 2-inch face, with countershaft and attachment for surface grinding and with 2 spare wheels.

One portable cylinder-boring machine, with latest attachments for boring cylinders in place. To bore from 6 to 24 inches diameter and to have at least 30 inches travel.

Six machinist's swivel bottom vises, with jaws at least 5¼ inches wide, opening 8 inches, with pipe vise jaws and copper vise lips.

One approved steel blacksmith's forge, of the portable folding type, with all the necessary tools and fixtures. The blast wheel to be about 12 inches diameter, turned by a crank. The gearing enclosed in a dust-proof case. When set up, the pan to be about 24 inches square. The pan and hood to form a case which, when the forge is dismantled and the parts placed inside, will be a strong, impact, steel box, provided with handles for carrying. This forge will be supplied with a set of tools of assorted sizes, consisting of the following: 6 pairs tongs, 4 chisels, 6 punches, 4 hammers, 3 sledges, 6 sets swages, 6 sets of fullers, 1 flatter, 1 hardy, and 1 set hammers.

There will be provided and set in the blacksmith shop an approved blacksmith's forge, about 42 inches square by about 25 inches high. Forge to be complete with tuyere, blast gate, pipe connecting as directed, etc., and with a set of tools of assorted sizes consisting of the following: 6 pairs of tongs, 4 chisels, 6 punches, 4 hammers, 3 sledges, 6 sets of swages, 6 sets of fullers, 1 flatter, 1 hardy and 1 set hammers.

One steel blacksmith's anvil of 140 pounds weight, face 14 inches by 4 inches, horn 8½ inches long, with a cutter hole ⅞ inch square.

All tools to be the best design, material, quality and workmanship, to have the latest improvements and all necessary attachments, wrenches and countershafts, and, when required, provision will be made for working them by hand.

The lathes to have a complete set of change gears for cutting U. S. N. standard screw threads, including 11½ threads per inch.

When submitted for approval there must be furnished full descriptions, cuts or drawings showing details of the machine, also the name of the maker, the net weight, the space occupied, and a list of the tools and attachments.

All machines to be furnished complete with a full set of cutting tools and all necessary attachments for miscellaneous work.

The machine tools will be driven by one or more inclosed motors, either directly or through the medium of line and countershafting as approved.

All of the above tools will be subject to the approval of the Bureau of Steam Engineering.

The following are the specifications for the machine tools for the scout cruisers.

### MACHINE TOOLS.

There will be provided and installed in the general workshop the following machine tools, viz:

One screw-cutting, back-geared, extension-gap lathe, to swing at least 28 inches over the upper and 48 inches over the lower ways, with not less than 10 feet between the centers, when extended. To have hollow-spindle compound rest, steady and follow rests, power cross feed, taper attachment, countershaft, 2 face plates, 1 large and 1 small chuck, 1 drill chuck and a complete set of at least 16 lathe tools and 7 lathe dogs.

One screw-cutting, back-geared tool-room lathe, to swing at least 14 inches over the ways and not less than 4 feet between the centers. To have quick-change feed gear, power cross feed, hollow-spindle taper attachment, oil pan, 1 large and 1 small face plate, counter shaft, 1 large and 1 small chuck and drill chuck, drawing-in attachment, with complete set of chucks, a set of at least 12 lathe tools and 6 lathe dogs.

One column tool-room shaper of at least 15-inch stroke and not less than 15-inch traverse. To have automatic stop, adjustable table, and graduated swivel vise with jaws for taper work, 24-inch graduated index center and a set of at least 12 shaper tools.

One upright drill, to drill up to 1½ inches, to have at least 14 inches from edge of work, to have not less than 14 inches of traverse of spindle, to be fitted for No. 4 Morse taper, with requisite number of sockets. To have a complete set of twist drills from ¼ to ⅝ inch by 32ds, and from $\frac{11}{16}$ to 1½ inches by 16ths. To have automatic and hand-feed, sliding head, counterbalanced spindle, circular table, revolvable by gear and adjustable vertically by gear, automatic stop, tapping attachment, countershaft and a small drill chuck fitted.

One 16-inch sensitive drill, to have a counterbalanced spindle fitted for No. 1 Morse taper, sliding head, table, to have vertical adjustable movement, to drill holes up to ⅝-inch with drill chuck and complete set of drills from $\frac{1}{16}$ to ⅝ inch by 32ds.

One universal milling machine with overhanging arm; to have at least 18-inch longitudinal feed of table, 13-inch vertical movement, and 4½-inch traverse. Spindle to be fitted for No. 9 B. & S. taper. To have automatic cross feed, universal chuck, arbor, index, swivel vise, spiral cutting attachment, countershaft, 3 milling cutters, 2 side millers, 6 metal slit saws, 3 angular cutters, 4 end mills and 2 collets.

One combined hand punch and shears with 6-inch shear blades, to cut ¾-inch round iron, shear ⅜-inch steel plate, and punch ⅜-inch holes in ⅜-inch mild-steel plates 4 inches from edge.

One double emery grinder on column, with carborundum wheels, 12-inch diameter by 2-inch face, with countershaft and attachment for surface grinding and with 2 spare wheels.

One, portable cylinder-boring machine with latest attachments for boring cylinders in place. To bore from 6 to 24 inches diameter and to have at least 30 inches travel.

Six machinist's swivel-bottom vises, with jaws at least 5¼ inches wide opening 8 inches, with pipe-vise jaws and copper vise lips.

One approved steel blacksmith's forge, of the portable folding type, with all the necessary tools and fixtures. The blast wheel to be about 12 inches diameter turned by a crank. The

gearing enclosed in a dust-proof case. When set up, the pan to be about 24 inches square. The pan and hood to form a case which, when the forge is dismantled and the parts placed inside, will be a strong, impact, steel box, provided with handles for carrying. This forge will be supplied with a set of tools of assorted sizes, consisting of the following: 6 pairs tongs, 4 chisels, 6 punches, 4 hammers, 3 sledges, 6 sets swages, 6 sets of fullers, 1 flatter, 1 hardy and 1 set hammers.

There will be provided and set in the blacksmith shop an approved blacksmith's forge about 42 inches square by about 25 inches high. Forge to be complete with tuyere, blast gate, pipe connecting as directed, etc. And with a set of tools of assorted sizes consisting of the following: 6 pairs of tongs, 4 chisels, 6 punches, 4 hammers, 3 sledges, 6 sets of swages, 6 sets of fullers, 1 flatter, 1 hardy and 1 set hammers.

In addition to the accessories enumerated above the following are desirable:

For large lathe: Pipe center to fit tail stock, to be used in turning pipe;

Bell center for centering pipes;

Two centering tools, same size as pipe center;

One center grinder to fit tool post head;

Additional lathe tools for special work;

For small late: One steady rest;

One follower set;

Pipe center to fit tail stock;

Bell center, same as pipe center;

Armstrong tool holder;

One center grinder;

Two centering tools, the same size as the pipe centers.

For drill press: One boring bar complete with tapered shank.

Machine tools on board ship are driven by independent electric motors, by a motor driving shafting from which each tool is operated by a belt, and by a small steam engine driving shafting.

The most approved system is considered to be that where each tool is driven by its own motor. This dispenses with the use of shafting and belts, and thus gives greater space and facilities for handling work about the machines.

The following is a list of material for use in work shop:

Castings: Hard cast iron, hollow, of various diameters, for making packing rings, valve-chest liners, etc.

Steel billets: For making crosshead and crank pins of auxiliaries, especially for blowers, ice machines and ash hoists.

Iron bar: Round and flat, of various sizes, for brackets, ties, supports, etc.

Steel bars: For making extension spindles, valve stems and piston rods of auxiliaries.

Tool steel: For making chisels, tools and special wearing parts.

Brass castings, various sizes: For making brass fittings of different kinds.

Brass and Manganese-bronze rods, round and hexagonal; For making brass valve stems, valves, bushings and other fittings.

Sheet brass, assorted sizes: For liners, shims, distance pieces and pipe covering.

Sheet copper: For gaskets and pipe covering.

Spring steel and brass: For springs.

Sheet iron, plain and galvanized: For making covers, tanks, shelves, etc.

Brass, iron and copper piping of various sizes.

Copper tubing: For small steam pipe and gauge connections.

Other accessories to the machine shop are surface plates, usually a small and a large one, plate gages, sets of taps and dies for bolts and nuts, sets of pipe taps and dies, pipe cutters, pipe wrenches, corrugating machine for corrugating copper gaskets, electric and pneumatic drills and hammers, buffing wheel to be used on emery grinder spindle for polishing.

## OUTFIT OF TOOLS AND SPARE PARTS.

On commissioning, vessels are furnished by the builders with an outfit of special tools and spare parts. These may be considered as a permanent outfit; additional tools, gear and supplies are furnished from the General Storekeeper of the Navy Yard in accordance with the allowance list of the vessel.

The following are the latest requirements of the machinery specifications for the permanent outfit of tools and spare parts.

The following tools will be provided for the engine and firerooms, viz:

Two ratchets for turning gear.

One wrench for propeller-blade nuts.

One wrench for propeller-shaft nuts.

One set of casehardened wrenches, with racks for each auxiliary engine, to be secured to the bulkhead near its engine.

One set of wrenches complete for each engine and fireroom, fitted for all nuts in the respective compartment, plainly marked as to size and any special use, and fitted in iron racks of approved pattern. The set will include duplicates of all special wrenches found to be necessary in erecting and installing the machinery.

Wrenches for nuts of bolts less than 1 inch in diameter will be finished. For sizes over 2 inches they will be box wrenches, where such can be used. Socket wrenches will be furnished where required. Open-end wrenches will be of forged steel with casehardened jaws; all others will be of forged or cast steel.

A fixed trammel for setting the main valves without removing the covers. The valve stems will be properly marked for this purpose.

Fixed trammels or gauges for aligning crank shafts.

Two tube expanders for evaporator tubes.

One tube expander for feed-heater tubes.

One tube expander for distiller tubes.

A hydraulic jack of approved pattern for withdrawing the bolts of the main-shaft couplings.

One boiler-test pump, with gauge, to test up to 500 pounds;

to be fitted with 10 feet suction and 24 feet pressure hose of sizes to suit pump, with couplings and connections complete.

Steel templets, ⅛ inch thick, of the bore in propeller hubs.

One hundred condenser-tube plugs, brass, hollow, threaded same as ferrules.

One hundred feed-heater-tube plugs, cast iron, slightly tapered.

Scrapers for brasses, of various sizes and shapes.

Three portable workbenches for firerooms, to be easily taken apart or bolted together. Each to be fitted with Parker's combination vise or equivalent, for holding 3-inch pipe or under; to be 2 feet 6 inches high, 2 feet 6 inches wide, and 4 feet long.

Planks of suitable lengths and dimensions, properly shaped for use as staging about crank pits.

Boxes for cleaning gear, 12 by 6 by 5 inches, to be strongly made of galvanized iron, with vertical partition in middle and with handle in end to draw from shelf; this end stamped "U. S. S.———, Engineer Dept."

Pigeonhole cabinet shelves for stowing the above boxes, to be strongly made of galvanized iron and placed where directed.

Brass lamp trays, about 4 feet by 27 inches, to be about 4 inches deep and provided with perforated division plates in three sections, so as to be easily lifted out. To have drain-cock and to be secured in shaft alley as directed.

Flanges, for copper steam pipes, of brazing material, as per sketches to be furnished. These flanges to be faced, grooved, and ready for use, except that bolt holes are not to be drilled.

Any special or unusual gear for engine-room telegraphs.

Any special or unusual gear, knuckle joints, bevel gears, etc., for revolution indicator.

Dies for making copper gaskets.

There will be the following tools and stores for the boiler rooms:

Two sets of fire tools for each fireroom. A set of fire tools will comprise two long and two medium-length slice bars, two long and two medium-length fire hoes, one long and one medium-length ash hoe (each hoe with one spare blade), two devil's claws, two pricker bars, two soot hoes, four coal buckets, and two ash buckets.

Racks will be fitted in the firerooms, in convenient places, for holding the fire-tools.

Wrenches for boiler hand-hole nuts, two for each boiler.

Wrenches for superheater hand-hole nuts, one for each boiler.

Wrenches for boiler manhole nuts, one for each boiler.

Suitable wire and bristle brushes for cleaning soot from exterior of tubes.

Tube scrapers with handles, two for each boiler.

Six tube expanders and mandrels, complete, for each size of generating tube.

Four tube expanders and mandrels, complete, for each of the other sizes used in assembling boilers.

Twenty-four plugs for each size of tubes used.

Four plug extractors.

Eight safety-valve gags.

All special tools used in assembling, repair, and cleaning of boilers, as directed.

One turbine tube cleaner for each two boilers, for each size of generating tube, all to be provided with flexible hose.

Four patterns for grate bars.

One pattern for furnace dead plates.

One pattern for fire-door lining.

One pattern for each special form of zinc protector used in boilers.

One set of steel templets, $\frac{1}{16}$ inch thick, for all manhole and hand-hole plate gaskets, each plainly marked to show for which gasket.

Other tools, etc., as may be directed, depending on the type of boiler adopted.

All tools will be conveniently stowed and trammels and gauges will have protecting cases.

## SPARE PARTS.

Spare parts will be furnished in accordance with the following tables.

Where machinery not here mentioned or auxiliaries of a different type are installed, spare parts will be furnished in accordance with lists prepared or approved by the Bureau of Steam Engineering.

*Spare Parts for Main Engines.*—The following spare parts for main engines will be furnished and carried on board:

| Part. | Number to be furnished. |
|---|---|
| Piston rods | 1 of each size and pattern. |
| Valve stems | 1 of each size and pattern. |
| Crosshead slippers | 1 of each size and pattern. |
| Metallic packing, piston rods | All for both engines. |
| Metallic packing, valve stems | All for both engines. |
| Eccentric straps, bolts and liners, complete | 1 set of each pattern. |
| Crank-pin brasses, top | 1 of each pattern. |
| Crank-pin brasses, bottom | 1 of each pattern. |
| Liners for crank-pin brasses | 2 of each pattern. |
| Bolts for crank-pin brasses | 2 of each pattern. |
| Crosshead-pin brasses, top | 2 of each pattern. |
| Crosshead-pin brasses, bottom | 2 of each pattern. |
| Liners for crosshead-pin brasses | 4 of each pattern. |
| Bolts for crosshead-pin brasses | 4 of each pattern. |
| Eccentric-rod brasses, top | 2 of each pattern. |
| Eccentric-rod brasses, bottom | 2 of each pattern. |
| Liners for eccentric-rod brasses | 4 of each pattern. |
| Main-bearing brasses, top if fitted | 1 of each pattern. |
| Main-bearing brasses, bottom | 1 of each pattern. |
| Liners for main bearings | 2 of each pattern. |
| Bolts for main bearings | 4 of each pattern. |
| Valve-gear brasses, bushings, etc., not specifically mentioned above | 1 of each size and pattern. |
| Piston rings, complete | 1 for each piston. |

| Part. | Number to be furnished. |
|---|---|
| Piston-ring springs | All for each piston. |
| Piston-follower bolts and nuts | 25 of each size and pattern. |
| Cylinder-head bolts | 25 of each size and pattern. |
| Coupling bolts and nuts | 3 of each size and pattern. |
| Split pins, special | 2 of each size and pattern. |

*Boiler Spares.*—The following spare parts will be furnished and carried on board:

| Part. | Number to be furnished. |
|---|---|
| Grate bars | Complete for 3 boilers. |
| Bearers | Complete for 3 boilers. |
| Dead plates | Complete for 3 boilers. |
| Furnace door frames, complete | Complete for 3 boilers. |
| Furnace-door linings | Complete for 3 boilers. |
| Ash-pit doors | Complete for 2 boilers. |
| Boiler-manhole plates, with bolts, nuts and dogs | Complete for 2 boilers. |
| Gauge cocks | Complete for 2 boilers. |
| Water gauges, complete | Complete for 2 boilers. |
| Feed check valves | 2 to each hand. |
| Surface blow valves | 1 to each hand. |
| Bottom blow valves | 1 to each hand. |
| Hand-hole plates, with bolts, nuts, and dogs | 5 per cent. of all, including superheater. |
| Special fire brick | 10 per cent. of all. |
| Special fittings | As may be directed. |
| All tubes of each size and shape, including superheater | 8 per cent. |
| Springs for boiler safety valves | 2 of each size. |

*Miscellaneous Spare Parts.*—The following miscellaneous spare parts will be furnished and carried on board:

| Part. | Quantity to be furnished. |
|---|---|
| Condenser tubes of each length | 5 per cent. |
| Feed-water heater tubes | 10 per cent. |
| Distiller tubes | 100 per cent. |
| Evaporator tubes | 25 per cent. |
| Condenser-tube ferrules | 10 per cent. |
| Springs for all safety valves except boiler safety valves | 1 of each size, pressure and type. |
| Springs for all relief valves | 1 of each size, pressure and type. |

| Part. | Quantity to be furnished. |
|---|---|
| Springs for all reducing valves | 1 of each size, pressure and type. |
| Diaphragms for reducing valves | 2 of each size, pressure and type. |
| Removable seats for all gate valves | 2 of each size and type. |
| Nozzles and flexible metallic tubing of steam tube cleaners | 50 per cent. |
| Zincs not made from standard plates | 100 per cent. |
| Thrust-bearing horseshoes | All, for either bearing. |
| Baskets for bilge strainers | 100 per cent. |
| Collar bolts for condenser heads | 25. |

*Spare Parts for Auxiliary Engines.*—The following spare parts for auxiliary engines will be furnished and carried on board:

| Part. | Circulating-pump engines. | Turning engines. | Workshop engine, if fitted. | Reversing engines. | Forced-draft blower-engines, if fitted. |
|---|---|---|---|---|---|
| Connecting rods, of each size and pattern fitted | 1 | ... | ... | ... | 6 |
| Eccentric rods, straps, bolts and nuts, of each size and pattern fitted | 1 | 1 | ... | ... | 6 |
| Piston rods and nuts, complete with crossheads and slippers, of each size and type fitted | 1 | 1 | ... | ... | 6 |
| Valve stems and nuts, complete, of each size and pattern fitted | 1 | 1 | ... | ... | 6 |
| Brasses and bushings, for each one fitted | 1 | 1 | 1 | 1 | 1 |
| Bolts and nuts of crank-pin and crosshead brasses, of each size and pattern fitted, sets | 1 | 1 | 1 | ... | 6 |
| Metallic packing for all glands, for each size and pattern fitted.....sets | 4 | 1 | 1 | 1 | 12 |
| Cup leathers.....sets | ... | ... | ... | 2 | ... |
| Packing rings for pistons and piston valves, for each size and pattern fitted | 1 | ... | ... | ... | 6 |
| Springs for pistons and all other parts, for each size and pattern fitted.....sets | 1 | ... | ... | .. | 12 |

*Spare Parts for Pumps.*—The following spare parts will be furnished and carried on board:

| Part. | Main air pumps. | Auxiliary and dynamo air and circulating pumps. | Feed pumps, main and auxiliary. | Fire and bilge pumps. | Distiller circulating pumps. | Evaporator feed pumps. | Distiller fresh-water pumps. | Oil pumps. | Shaft pumps. | Other pumps. |
|---|---|---|---|---|---|---|---|---|---|---|
| Steam piston rods and nuts, complete, for each size and pattern fitted | 1 | 1 | 1 | 1 | 1 | 1 | 1 | ... | ... | 1 |
| Pump rods and nuts, complete, for each size and pattern fitted | 1 | 1 | 1 | 1 | 1 | 1 | 1 | ... | ... | 1 |
| Valve stems and nuts, complete, for each size and pattern fitted | 1 | 1 | 1 | 1 | 1 | 1 | 1 | ... | ... | 1 |
| Pump valves, with guards, guard bolts, and springs | All | All | All | All | All | All | All | All | All | All |
| Metallic packing, for glands, for each size and pattern fitted, sets | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| Packing rings for steam pistons and piston valves, for each size and pattern fitted | 1 | 1 | 1 | 1 | 1 | 1 | 1 | ... | ... | 1 |
| Packing rings for water pistons, for each size and pattern fitted | 1 | 1 | 1 | 1 | 1 | 1 | 1 | ... | ... | 1 |
| Springs for pistons and all other parts, for each size and pattern fitted, sets | 1 | 1 | 1 | 1 | 1 | 1 | 1 | ... | ... | 1 |
| Brasses and bushings for every purpose, for each one or pair, of each size or pattern | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

*Spare Parts for Electric Motors under Steam Engineering.*—The following spare parts will be furnished, and carried on board, for each motor:

1 armature, complete with shaft.
1 field coil.
1 set of bearing bushes or linings, complete.
1 set of brush studs, with insulation.
½ set of brush holders.
6 sets of carbon brushes.

1 set of carbon breaks.
2 oil-gauge glasses.
1 set of contacts.
1 set of resistances, completely assembled.
10 inclosed fuses.

Armatures over 120 pounds in weight are to be stowed by supporting the shafts on brackets, secured to the bulkhead, the armature to be incased in a protecting casing of No. 18 U. S. S. G. galvanized steel, in halves, secured by hooks. The journals to be neatly covered with tarred canvas.

Armatures under 120 pounds in weight are to be stowed in plain wooden boxes with hinged covers, hinged hasp, and lock, the armature to be mounted on chocks in such a manner that it can be revolved by hand to permit inspection of all parts. The chocks should be so fitted that the armature can be removed or replaced without damage to it.

Field coils may be stowed in the same box with the armature but in a separate compartment. When the armatures are stowed on brackets, the field coils must be stowed in boxes.

*Spare Parts for Air Compressors.*—Spare parts for air compressors will be furnished and carried on board. These spare parts will depend upon the type of machine adopted, and a list will be submitted to the Bureau for approval when drawings of air compressor are submitted.

*Spare Parts for Ice Machines.*—The following spare parts will be furnished, and carried on board, for each ice machine:

| Part. | Number to be furnished. |
|---|---|
| Valve stems for steam valve, compressor distributing valve, compressor cut-off valve, expander distributing valve, expander cut-off valve. | 1 of each size and pattern. |
| Piston rods for steam, compressor, and expander cylinders. | 1 of each size and pattern. |
| Eccentric rods | 1 of each size and type. |
| Crank-pin brasses for steam, compressor and expander cylinders. | 1 set for each, of each size and pattern. |
| Crosshead brasses for steam, compressor and expander cylinders. | 1 set for each, of each size and pattern. |
| Rock-shaft bearing brasses | 4 sets. |
| Valve-rod bushings | 10. |

| Part. | Number to be furnished. |
|---|---|
| Valves with guards and springs for circulating pump and primer pump. | 1 set of each, of each size and pattern. |
| Springs for steam pistons | ½ set for each. |
| Cooling coil | 1. |
| Packing for piston rods and valve stems | 1 set for each set fitted. |
| Packing, leather | 6 sets for each set fitted. |
| Thermometers | 1 for each fitted. |
| Wrenches | 1 set complete. |

*Spare Parts not Carried on Board.*—The following spare parts, not carried on board and not included in the penalty weight, will be furnished:

| Part. | Number to be furnished. |
|---|---|
| Main propeller shaft | 1. |
| Main-engine crank shaft | 1 of each pattern. |
| Propeller blades | All. |
| Evaporator steam heads | All. |
| Boiler tubes, of each size and shape | ¼ of total number fitted. |
| Boiler-tube nipples | ¼ of total number fitted. |

The packings for compressor and expander cylinders of ice machines will be securely and separately packed in tight boxes with covers and filled with castor oil.

All spare parts will be finished and fitted ready for use, as specified above, and stowed in an approved manner.

Boiler tubes will be securely stowed in racks, or as directed.

Condenser tubes will be packed in boxes. All brass pieces will be stamped with name, and finished pieces, liable to corrode, will be painted with three coats of white lead and oil, and well lashed in tarred canvas, with the name painted on outside.

The spare propeller blades will be of such pattern as may be directed after trial of vessel.

The spare shafts, propeller blades, and such other spares as may be directed, will be packed for storage at a Navy Yard.

The following additional spares may be desirable:

*Main Engines.*—2 packing rings for each size of balance piston.

1 packing ring and follower for each size of piston valve.

*Boilers.*—Spare side and cross boxes where water-tube boilers are fitted with these.

*Ice Machines.*—100 feet galvanized-iron cooling pipe.

The following additional tools may be found desirable:

Set of star wrenches.

Clamp for turning out bottom main-bearing brasses.

## TESTS OF MACHINERY AND PIPING.

As a guide to tell what pressures may safely be allowed to be put on various parts of machinery and piping, the following tables giving the latest requirements of the machinery specifications will be valuable. Practically all parts of piping and chambers are fitted with relief valves designed to operate at pressures considerably below that of the test pressure. It is often, however, desirable to test certain parts for strength after being repaired.

*Tests of Boilers and Machinery.*—The following parts of machinery will be tested *before being placed on board the vessel:*

| Part. | Test pressure per square inch above atmosphere. *Pounds.* | Test. |
|---|---|---|
| Main boilers | 450 | By the application of heat to fresh water in the boilers, boilers being quite full. This test optional. |
| Circulating-pump casings | 30 | Water pressure. |
| Condenser shells and water chambers | 30 | Do. |
| Cylinders and all parts of auxiliary machinery subject to boiler pressure. | 450 | Do. |
| Cylinders, H.P., valve chests and connections. | 450 | Do. |
| Cylinders, I.P., valve chests and connections. | 200 | Do. |
| Cylinders, L.P., valve chests and connections. | 100 | Do. |
| Distiller heads, shells and tubes | 50 | Do. |
| Evaporator shells | 50 | Do. |
| Evaporator steam heads and tubes | 450 | Do. |
| Feed-water heaters when on suction side of pumps. | 100 | Do. |
| Feed-water heaters when on discharge side of pumps. | 500 | Do. |

| Part. | Test pressure. | Test. |
|---|---|---|
| Fittings and connections subject to boiler pressure. | 450 | Water pressure. |
| Pumps, feed, water cylinders, valve chests and air vessels. | 500 | Do. |
| Pumps, fire and bilge, water cylinders, valve chests and air vessels. | 225 | Do. |
| Shaft casings after being fitted on shafts. | 30 | With boiled linseed oil. |
| Tanks, air compressor | 150 | Water pressure. |
| Tanks, feed, filter, hot well, distiller, reservoir, soda, oil, tallow, waste, store, etc. | 10 | Do. |
| Other parts and tests | As directed | As directed. |

Parts to be tested will be so placed that all parts are acessible for examination by the inspector during the tests.

Pipes will be tested, by water pressure, before being placed on board, as follows:

| Pipes. | Test pressure. *Pounds.* |
|---|---|
| Air pump, main and auxiliary, suction and discharge | 50 |
| Bilge discharge | 150 |
| Bilge suction | 100 |
| Bleeder | 450 |
| Blow, boiler | 450 |
| Blow, evaporator | 100 |
| Boiling-out condensers | 450 |
| Circulating pumps, main and auxiliary, suction and discharge | 100 |
| Distiller, circulating | 100 |
| Distiller, fresh water | 100 |
| Drains, crank pit | 50 |
| Drains to traps | 450 |
| Drains, separator | 450 |
| Drainage suction | 100 |
| Escape | 30 |
| Exhaust, auxiliary | 50 |
| Exhaust, branch | 50 |
| Exhaust, dynamo | 50 |
| Exhaust, to atmosphere | 50 |
| Exhaust, to feed heater | 50 |
| Exhaust, main | 50 |
| Feed, discharge | 450 |
| Feed, evaporator | 100 |
| Feed, suction | 100 |
| Fire extinguishing on grates | 100 |
| Fire-main supply connections | 225 |

| Pipes. | Test pressure. *Pounds.* |
|---|---|
| Fire main to stern tubes | 225 |
| Fireroom hydrants | 100 |
| Fresh water from ship's side | 100 |
| Fresh-water pumping system | 100 |
| Indicator | 450 |
| Jacket steam | 450 |
| Overboard discharge | 150 |
| Overflow from feed tanks | 30 |
| Pneumatic main | 150 |
| Pumping-out boilers | 450 |
| Receiver, I.P. | 200 |
| Receiver, L.P. | 100 |
| Refrigerating plant, air pipes | 250 |
| Reserve feed-tank connections | 100 |
| Sanitary connections | 100 |
| Sea suctions | 100 |
| Shaft bilge-pump discharges | 150 |
| Shaft bilge-pump suctions | 100 |
| Steam, auxiliary | 450 |
| Steam, branch | 450 |
| Steam, galley | 450 |
| Steam, dynamo | 450 |
| Steam, main | 450 |
| Steam, radiators | 150 |
| Steam, from evaporators | 100 |
| Steam, to evaporators | 450 |
| Steam, to I.P. receiver | 450 |
| Steam, to L.P. receiver | 450 |
| Steam, to sea valves | 450 |
| Vapor | 30 |
| Water service | 50 |
| Whistle and siren | 450 |
| Other pipes | As directed. |

Valves, manifolds, and castings for pipes will be tested, by water pressure, before being placed on board, as follows:

| Valves, manifolds, and castings. | Test pressure. *Pounds.* |
|---|---|
| Feed valves and castings | 500 |
| Steam valves | 450 |
| Exhaust valves | 100 |
| Water valves, low-pressure | 100 |
| Composition castings for feed | 500 |
| Steel castings for steam | 450 |
| Composition castings for low-pressure | 100 |

The following parts of machinery will be tested *after being placed on board the vessel:*

| | Test pressure per sq. in. above atmos. | Test. |
|---|---|---|
| | *Pounds.* | |
| Main boilers ..... | 450 | By the application of heat to fresh water in the boilers, the boilers being quite full. |
| Main boilers and pipe connections.. | 375 | By steam, and all leaks to be made tight before parts are clothed and lagged. |
| Main and auxiliary feed systems as a whole, installed and connected, from and including the pressure parts of the pumps up to the valves on the boilers. | 500 | Water pressure. |
| All parts after being secured on board. | Working pressures. | Under working conditions. |
| Other parts and tests..... | As requ'd. | As directed. |

The circulating pumps will be tested by discharging water under a head of 25 feet, 5 feet of which will be suction.

The suction and discharge pipes, during the test, will be the same size as the nozzles on the pumps.

A four-hour test of evaporating and distilling plant will be made under service conditions, using sea-water feed, and maintaining a density of $\frac{3}{32}$ in the evaporators.

No lagging or covering will be on cylinders, pipes or condensers during the tests.

If india-rubber valves are used, they will be taken at random and must stand a dry-heat test of 270 degrees F. for one hour and a moist-heat test of 400 degrees F. for three hours without injury.

Steam will not be raised in the boilers until after the water test of boilers on board, unless desired for drying or testing joints, for which purpose the pressure will not exceed 10 pounds per square inch.

## CHARACTERISTICS OF DIFFERENT METALS.

Different metals vary in their power to resist hammering, bending or any other shock, and a due consideration of these properties will very often avoid a serious breakage.

*Cast Iron.*—This should never be subjected to heavy blows as it is brittle and will readily crack. It cannot be bent, and if sufficient force is applied it will break. It can stand a crushing stress very well, but no sudden shocks. Cast iron will also crack when subjected to sudden changes in temperature.

*Cast Steel.*—This will stand sudden blows and hammering and can also be bent to some extent, but is not easily deformed. It has very little flow under stress. It is more brittle and less liable to deformity and bending when subjected to blows than forged steel. Cast steel is very liable to crack when subjected to sudden changes of temperature.

*Forged Steel.*—This is tough and elastic and will withstand sudden shocks very well, and it can be bent without any great danger of cracking. It will not crack as readily as cast metal when subjected to changes in temperature.

*Forged Iron.*—This is tough and softer than steel, but not as strong. It can be bent without danger of cracking. Hammering will not cause it to crack, but will easily force it out of shape. Changes in temperature will not cause it to crack readily.

*Cast Brass or Composition.*—This, like other cast metal, is somewhat brittle. The larger the percentage of copper the less brittle will brass be, and the more will it be able to withstand hammering and bending. It will expand more when the temperature is raised, but will not crack as easily as cast iron when temperature is suddenly changed.

It will be noticed that cast iron should not be struck by blows nor should there be any endeavor to bend it or to bring it into shape by hammering. Cast steel can be bent, but should not be struck, as it may crack; the same may be said of composition.

In striking of metals that are likely to be deformed by the process, use a soft copper maul, and never a hammer of any material harder than that which is struck, since in that case the material struck will be deformed and the hammer retain its shape. When a soft hammer is used it will be knocked out of shape but the part on which it is used will not be deformed.

To prevent edges burring or causing deformity, place pieces of wood against the part struck. The blow will then be distributed over a greater area and the part struck will not be deformed. In handling a delicate piece in a vise, strips of wood or cloth should be used to protect the surface, which might be otherwise dented or grooved by the vise jaws.

## WEAR OF METALS ON EACH OTHER.

Whenever metal works on metal nearly all the wear will take place on the softer metal of the two; the softer will thus be worn away and the harder will retain its shape. This fact is often considered in arranging the various parts of machines so that the softer parts can be renewed and replaced. As a rule for wearing surfaces, two different kinds of metal are used. Cast iron will wear well on itself, but cast steel and forged iron will not. Brass will wear well on steel or cast iron.

## EXPANSION AND CONTRACTION OF METALS.

All metals in general contract with cold and enlarge when heated, but the relative amount of this extension differs widely for different materials.

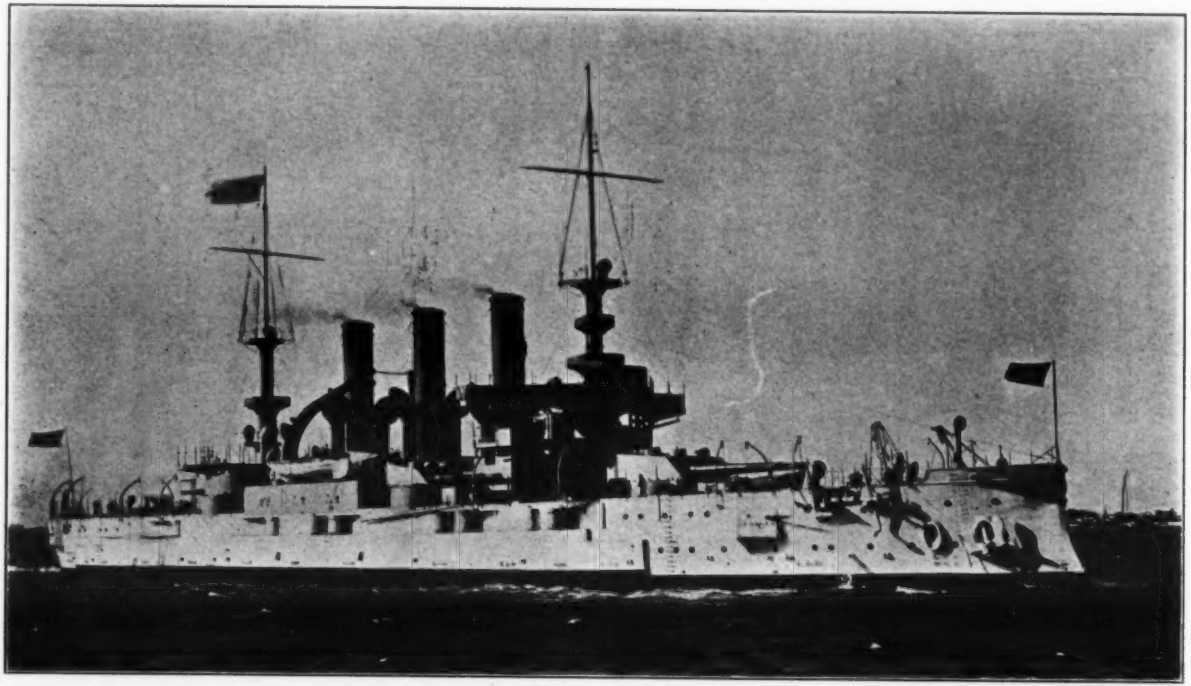
The extension per linear foot in inches for each degree in temperature Fahrenheit of metals ordinarily met with is as follows:

| | | | |
|---|---|---|---|
| Brass | .0125 | Steel, rod | .00763 |
| Cast iron | .0074 | Steel, cast | .0072 |
| Copper, from 0° to 212° | .0115 | Steel, tempered | .00826 |
| Copper, from 32° to 212° | .00418 | Steel, not tempered | .00719 |
| Gun metal | .0127 | Zinc, forged | .0207 |
| Iron, forged | .00814 | Zinc, sheet | .0196 |
| Iron, forged 0° to 212° | .00788 | Zinc, 81 tin | .0179 |
| Iron, forged, 32° to 212° | .00326 | | |

This property can often be made use of to loosen nuts that are frozen, which when heated up expand and can be moved. In connection with this it is well to note the different co-efficients of expansion as shown above.

The property of metals contracting when cooling can be made use of in bringing parts together with great force. If an iron clamp or ring is put on while hot, on cooling it will contract and grip tightly; and a rivet put in hot will draw the plates together. Collars and jackets are often shrunken on by being thus heated and then cooled after being put in place.

Water in freezing expands with great force and will cause the containing vessel to be fractured. Hollow shells have been broken in this way.



U. S. S. "VERMONT."

# U. S. S. *VERMONT.*

## DESCRIPTION AND OFFICIAL TRIAL.

The *Vermont* (first-class Battleship No. 20) built by the Fore River Shipbuilding Company of Quincy, Mass., is one of three first-class battleships authorized by Congress in an act approved March 3, 1903, and is the second of these three ships to have her trials.

The two sister ships are the *Minnesota,* building at Newport News, Va., and the *Kansas,* building at the New York Shipbuilding Company's Works, Camden, N. J.

The contract for the construction of the *Vermont* was concluded the 20th day of June, 1903, and provided for the delivery of this vessel in forty-two months from that date, that is, on or before December 20th, 1906. The time limit was extended to February 11th, 1907.

The contract price was $4,179,000, of which $1,000,000 was allowed for the building and complete installation of the machinery under cognizance of Bureau of Steam Engineering.

The guaranteed speed of the vessel on trial of four hours' duration was not less than an average of eighteen knots an hour, during which period an air pressure not exceeding one inch of water was allowed in the firerooms, and the vessel weighted to a mean draught of twenty-four feet six inches.

The designed indicated horsepower of the propelling engines was to be about 16,500 when making about 120 revolutions a minute with a steam pressure of 250 pounds.

Failure to attain the guaranteed speed of eighteen knots under the stipulated trial and conditions entails penalties at the rate of $50,000 per quarter knot for speed between 18 and 17¾ knots, and $100,000 a quarter knot for speed between 17¾ and 17½ knots, and that if the vessel should fail to exhibit an average speed of at least seventeen and one-half

knots an hour it should be optional with the Secretary of the Navy to reject her or to accept her at a reduced price and on conditions to be agreed upon.

COMPLEMENT.

| | | | |
|---|---|---|---|
| Admiral, | 1 | Seaman branch, | 401 |
| Chief of staff, | 1 | Artificer branch, | 44 |
| Commanding officer, | 1 | Engine-room branch, | 226 |
| Wardroom officers, | 19 | Special branch, | 17 |
| Junior officers, | 20 | Messmen branch, | 44 |
| Warrant officers, | 9 | Marines, | 72 |
| | 51 | Additional for flag, | 36 |
| | 840 | | 840 |
| Total, | 891 | | |

GENERAL HULL DATA.

| | |
|---|---|
| Length between perpendiculars, feet and inches | 450-00 |
| Projection forward of F. P., feet and inches | 6-04 |
| aft of A. P., feet and inches | 0-00 |
| Length over all, feet and inches | 456-04 |
| of L. W. L., feet and inches | 450-00 |
| between perpendiculars, feet and inches | 450-00 |
| Breadth, molded, feet and inches | 76-05½ |
| extreme, feet and inches | 76-10 |
| Depth, molded, main deck side at M. S. (56½), feet and inches | 43-01⅜ |
| Draught, trial, feet and inches | 24-06 |
| Ratio, length to beam | 5.856 |
| Displacement (normal, 24 feet 6 inches draught), trial, tons | 16,000 |
| (Estimated 900 tons coal, 50 tons reserve feed water.) | |
| Area midship section, square feet | 1,808 |
| L. W. L. plane, square feet | 26,560 |
| wetted surface, square feet | 44,500 |
| C. G., L. W. L. plane aft of M. S. (56½), feet | 4.4 |
| C. B. above bottom of keel, feet and inches | 13-04 |
| aft of M. S. (56½), foot | .765 |
| Transverse metacenter above C. B., feet and inches | 18-09½ |
| Longitudinal metacenter above C. B., feet and inches | 538-06 |
| Coefficient of fineness, block | .6592 |
| midship section | .9604 |
| L. W. L. plane | .7683 |
| cylindrical | .6873 |

Shafts incline up and aft at angle of 55 minutes 42 seconds.
Diverge at angle with center line of 25 minutes 41.2 seconds.

Center line at 72 : 10 feet 6 inches from center line of ship, 7 feet ⅛ inch from base line.
Center line 12 inches aft 108 : 11 feet 7 inches from center line of ship, 9 feet 4⅛ inches from base line.
Rake up, .19446 inch per foot ; out, .08966 inch per foot.

| | |
|---|---|
| Screws, diameter, feet and inches | 17–09 |
| pitch, adjustable 17 feet to 19 feet, feet and inches | 18–00 |
| area expanded, square feet | 93.0 |
| projected, square feet | 71.05 |
| center forward of A. P. (26 inches aft 108), feet and in. | 16–10 |
| Rudder axis forward of A. P. (3 feet 9 inches aft 108), feet and in. | 15–03 |
| Strut center line forward of A. P. (20 inches forward 108), feet and inches | 20–08 |
| Number of frames (spaced 4 feet throughout) | 112 |
| Watertight compartments | 314 |

## GENERAL DESCRIPTION.

The hull is made of basic, open-hearth steel, with frames spaced 4 feet apart, except under the engine compartment, where the frames are spaced 2 feet apart.

The inner bottom extends from frame 12 to frame 98. The double-bottom compartments between frames 58½ and 67½ are arranged for use as reserve-feed tanks, and will hold 150 tons of feed water. A cofferdam, 30 inches in width, extends the entire length of the ship about the protective deck, being carried to a height of 3 feet above the protective deck, and is packed with corn-pith cellulose in those parts forward and abaft the midship armor. All unexposed decks throughout the ship are covered with linoleum, except in the magazines and certain storerooms which are fitted with wood shutters, and in rooms, water closets, etc., where tiling is used.

*The Superstructure.*—The superstructure, built on the main deck, extends from frame 35 to a point 21 inches abaft frame 79, or between the 12-inch turrets; it extends the full width of the ship between the forward and after pairs of 8-inch turrets; it is recessed to make room for these turrets, and is cut away to permit a dead-ahead fire for the forward pair and a dead-astern fire for the after pair of 8-inch turrets. It is also cut away at the corners to give an arc of fire of 135 degrees for the 12-inch guns, forward and aft.

*The Bridge Deck.*—The bridge deck forms the top of the

superstructure. Over the forward end is built the forward bridge, on which is the chart house, emergency cabin, entrance to conning tower and the torpedo-directing station, which is joined to the forward side of the conning tower. Over the forward bridge is the usual flying bridge, on which are the steering compass, two searchlights and the usual navigating instruments. The standard compass is mounted on top of the chart house.

On the after end of the bridge deck is the after bridge, from which is the entrance to the armored signal tower.

*Top Hamper on the Superstructure.*—There is one electric boat crane on each side of the ship, of 15-tons capacity, located abreast of the after funnel. The boats, with the exception of two 30-foot whaleboats, 30-foot barge, 30-foot gig whaleboat, and two 30-foot cutters, which are on the main-deck davits, are stowed on the bridge deck. The dinghies are located abaft the after funnel, between the recesses for the after pair of 8-inch turrets, the 16-foot dinghy nested in a 20-foot dinghy on port side near center of ship, and the 14-foot dinghy in the other 20-foot dinghy on starboard side near center line. The other boats are stowed abreast in wake of the middle and after funnels. Beginning outboard, those located under starboard crane are: one 50-foot steam cutter, which is temporarily replaced by a 40-foot steam cutter; one 36-foot steam cutter, and one 30-foot cutter, which is nested in a 33-foot launch. Under the port crane are: one 36-foot steam cutter; a nest of one 30-foot cutter; one 33-foot launch and one 36-foot launch; and a nest of one 30-foot cutter and a 33-foot launch.

*Main Deck.*—The main deck extends the full length of the vessel, the superstructure partially covering it, as described above. At the bow is a waist plate, 3 feet 6 inches high, extending aft to frame.

*Anchors, etc.*—There is one anchor crane on each side, for handling Navy-type sheet anchors, bill boards for which are located between frames 9 and 13. There is, however, but one Navy-type anchor provided, which weighs 17,490 pounds, and

which is stowed on the starboard bill board. The tackles for these cranes are operated by electric winches abreast windlass house. There are two hawsepipes on each side, opening through this deck on to the forecastle, from which the chains have a direct lead to the windlass house, which is in front of the forward 12-inch turret and projects above the deck so that the chains enter the front, directly to the wildcat. In the forward hawsepipes are carried two 17,350-pound Baldt stockless anchors. There are also two kedge anchors, weighing 810 and 410 pounds, carried forward, and a 5,655-pound stern anchor and a 4,160-pound stream anchor, carried aft, all stowed against plating of superstructure. Forward, two 20-foot dinghies are stowed for harbor position only and two 30-foot cutters permanently, and aft there are two 30-foot whale boats, a 30-foot barge and a 30-foot gig whale boat.

Within the superstructure, and at its forward end, is the crew's galley and mess issuing room; amidships is the officers' galley, and aft are the general mess pantry, paymaster's and executive offices, battalion lockers and wireless-telegraph room. Drying rooms are located around all funnels.

*Gun Deck.*—Forward, on this deck, are located the crew's showers and washroom, petty officers' and machinists' water-closets, and the staterooms of the sergeant of marines and master-at-arms. Between the 12-inch barbettes is the 7-inch battery, in which space are located the bakery, printing office, brigs, junior, warrant and wardroom officers' lavatories, baths and shower baths; armory and engineers', navigators' and ordnance officers' offices. Abaft of the after 12-inch barbette are the admiral's, captain's and chief-of-staff's quarters and eight wardroom staterooms.

The admiral's quarters are unusually spacious, and take up nearly the entire after part of this deck.

Due to the installation of 7-inch guns on this deck, the deck height is greater than has been previously customary, being 8 feet 7 inches between decks and 7 feet 9 inches to bottom of beams. This necessitated special arrangements for the hammock hooks, which extend about 7 inches below bottom of beams.

*Berth Deck.*—On this deck are located, beginning forward, lamp rooms, stowage for oils, paint-mixing rooms, commissary stores and band rooms, the isolation ward, sick bay and its bath, dispensary and operating room. The machinists' and petty officers' quarters and washrooms and the refrigerating plant are abreast the forward 12-inch barbette; adjoining these are the steam laundry, general mess stores and paymaster's issuing room. The firemen's and servants' washrooms are on the center line between uptakes and take up their entire length. Abaft of uptake is the evaporator room. The general workshop is over the engine space, between hatches. Abreast of the engine-room hatches and after barbette are the junior and warrant officers' quarters and mess rooms, on starboard and port sides, respectively. Abaft, are the wardroom officers' quarters; farther aft several showers are provided.

*Protective Deck.*—This deck extends the full length of the ship and is 3 inches thick on the slopes and 1½ inches on the flat. The cofferdam previously mentioned extends its entire length, and the spaces between the slopes and berth deck are used for stores, except from frame 40½ to 72, where the berth-deck coal bunkers extend to this deck.

*Platform Decks and Hold.*—There are two platform decks. On these decks are the magazines, storerooms, handling rooms, etc. On the upper platform are the 8-inch ammunition, forward fresh-water tanks, and one dynamo room at each end of the boiler compartments, and the steering gear and engine. On the lower platform are the 7-inch, 3-inch and 3-pdr. magazines and the forward and after torpedo rooms. In the hold are the chain lockers, magazines, 3-inch and 3-pdr., 1-pdr., 30-caliber and saluting powder, for naval-defense mines and torpedo war heads; also the after fresh-water tanks.

## ARMOR.

The side belt is a complete water-line belt, 9 feet 3 inches wide amidships, for the length of the lower casemate; forward, this width is reduced to 8 feet and aft to 71 inches; from

frames 24 to 95, or 285 feet in wake of machinery spaces, the thickness is 9 inches, parallel.

Forward and aft of these points the thickness is 7 inches at top, tapering to five inches at bottom, then reduced to five inches constant thickness, then to four inches constant thickness. Top of belt is a straight line 4 feet 3 inches above L. W. L.

Covering the middle length of the ship there is a lower casemate belt of 7-inch armor extending from the top of the heavy side belt to the lower edge of 7-inch gun ports, 2 feet 8 inches above the gun deck. Above this, and extending to the height of the main deck, is a 7-inch belt, which is bent in to form wing plates at the 7-inch gun ports.

Between the gun deck and the protective deck, at frames 24 and 94, there are athwartship casemate bulkheads 6 inches thick; these are outside of the 12-inch barbette. Between the gun and main decks are similar 6-inch bulkheads at frames 28 and 86, connecting to the 12-inch barbettes. These athwartship bulkheads connect the ends of the casemate armor, forming a complete central casemate.

Between the gun deck and main deck, athwartship, splinter bulkheads of nickel-steel are provided for protection of 7-inch battery, each gun being thus in an isolated protected compartment. These are of 60-pound plates and located at frames 36, 50, 57, 64 and 78; those in wake of boiler uptakes not being continuous, those at frames 36 and 78 being continuous. A continuous fore-and-aft splinter bulkhead of 80-pound nickel-steel plate is fitted between 12-inch barbettes. Armored hinged doors are fitted in splinter bulkheads where necessary to provide access.

The 12-inch barbettes are 10 inches in thickness at front and 7½ inches thickness at back, from the top to the gun deck, and 6 inches between gun deck and protective deck. The 12-inch turrets are 12 inches thick on slope, remainder being 8-inch, top plate 2½ inches.

The 8-inch barbettes are 6 inches thick at front and 4 inches thick at back, with tubes from main to gun decks of

3¾ inches and from gun to protective deck of 3 inches thick.

The 8-inch turrets are 6½ inches thick on slope, remainder 6 inches; top plates 2 inches thick.

The conning tower is 9 inches thick and fitted with a swing door. The armored tube for communication is 6 inches thick. The signal tower aft is 6 inches thick.

BATTERY.

The 12-inch guns are mounted in pairs in two elliptical, electrically-controlled balanced turrets, one forward and one aft on center line, each having an arc of fire of 270 degrees.

The 8-inch guns are mounted in pairs on four elliptical turrets, located two on each side and about equally spaced between the two 12-inch turrets. Each pair have an arc of fire of 145 degrees, the forward pairs from 90 degrees forward to 55 degrees abaft beam; after pairs, vice versa.

The 7-inch guns, twelve in number, are mounted singly on pedestal mounts with shields, in the central armored casemates on gun deck, each having an arc of fire of 110 degrees.

The secondary battery consists of twenty 3-inch R.F., twelve 3-pdr. semi-automatic Hotchkiss, two 1-pdr. H.R.F. automatic, two 30-caliber Gatling machine guns. Four 21-inch submerged torpedo tubes are provided for, two forward and two aft. There are two Barr and Stroud range finders, one in each upper military top.

The following table gives the location and train of all guns, viz:

Four 12-inch B.L.R., 135 degrees port and starboard of center line of ship.

No. 1, forward turret, right hand.
2, forward turret, left hand.
3, after turret, right hand.
4, after turret, left hand.

Eight 8-inch B.L.R.

No. 1, forward starboard turret, right hand, 90 degrees forward, 35 degrees abaft beam.
2, forward starboard turret, left hand, 90 degrees forward, 55 degrees abaft beam.

3, forward port turret, right hand, 90 degrees forward, 55 degrees abaft beam.
4, forward port turret, left hand, 90 degrees forward, 55 degrees abaft beam.
5, after starboard turret, right hand, 90 degrees aft, 55 degrees forward beam.
6, after starboard turret, left hand, 90 degrees aft, 55 degrees forward beam.
7, after port turret, right hand, 90 degrees aft, 55 degrees forward beam.
8, after port turret, left hand, 90 degrees aft, 55 degrees forward beam.

## Twelve 7-inch R.F., on gun deck.

Nos. 1 and 2, frame 31, 90 degrees forward, 26 degrees abaft beam.
3 and 4, frame 39, 73½ degrees forward, 42½ degrees abaft beam.
5 and 6, frame 53, 70 degrees forward, 46 degrees abaft beam.
7 and 8, frame 61, 46 degrees forward, 70 degrees abaft beam.
9 and 10, frame 75, 42½ degrees forward, 73½ degrees abaft beam.
11 and 12, frame 83, 26 degrees forward, 90 degrees abaft beam.

## Twenty 3-inch 50-caliber R.F.

Nos. 1 and 2, gun deck, frame 16½, 90 degrees forward, 30 degrees abaft beam.
3 and 4, gun deck, frame 101, 30 degrees forward, 90 degrees abaft beam.
5 and 6, gun deck, frame 109, 30 degrees forward, 90 degrees abaft beam.
7 and 8, main deck, frame 52½, 60 degrees forward, 60 degrees abaft beam.
9 and 10, main deck, frame 57, 60 degrees forward, 60 degrees abaft beam.
11 and 12, main deck, frame 61, 60 degrees forward, 60 degrees abaft beam.
13 and 14, upper deck, frame 36½, 90 degrees forward, 10 degrees abaft beam.
15 and 16, upper deck, frame 50, 90 degrees forward, 10 degrees abaft beam.
17 and 18, upper deck, frame 77½, 10 degrees forward, 90 degrees abaft beam.
19 and 20, forward bridge, frame 37, 90 degrees forward, 25 degrees abaft beam.

## Ten 3-pounder semi-automatic Hotchkiss.

Nos. 1 and 2, upper deck, frame 39½, 45 degrees forward, 45 degrees abaft beam.
3 and 4, upper deck, frame 75, 45 degrees forward, 45 degrees abaft beam.

5 and 6, forward bridge, frame 40¼.
7 and 8, after bridge, frame 74¼.
9 and 10, after bridge, frame 77¼.
11 and 12, after bridge, frame 79.

Two 1-pounder H.R.F., automatic.

Nos. 1 and 2, upper deck, frame 64¼.

Two machine guns, 30-caliber Gatling.

Nos. 1 and 2, forward bridge, frame 35.

Four torpedo tubes, 21 inches, 2 forward, 2 aft.

AMMUNITION SUPPLY.

Ammunition hoists are provided in number and speed designed to obtain as far as practicable a full supply of ammunition necessary for all guns firing at maximum speeds. In addition to the usual hoists in 8-inch and 12-inch turrets, there are twelve 7-inch hoists capable of handling either shell or charges, and fourteeen combined 3-inch, 3-pdr. and 1-pdr. hoists. All hoists not within the armored citadel are protected with 80-pound nickel-steel plates. In order to supply ammunition to the hoists located along the ammunition passages on each side of lower platform deck, four continuous-motion ammunition-belt conveyors, each about 80 feet in length, are provided. These convey the shell and charges from the magazines located forward and abaft the machinery spaces on that deck.

These conveyors are so designed as to deliver ammunition to any of the hoists, the two forward ones supplying forward hoists, and two after ones the after hoists. They can also be operated in reverse direction to take ammunition into magazines. The shells are carried to the conveyor loading table from the shell room by means of trolleys on overhead rails. Charges and fixed ammunition are carried to conveyor by hand. The magazines for 8-inch and 12-inch ammunition are located on upper platform deck forward and abaft the machinery spaces. The 8-inch ammunition is carried from the magazines to base of turrets through the passages on differential blocks running on overhead trolleys. The 12-inch

magazines are located adjacent to the handling rooms for those turrets.

All the 7-inch hoists combined can hoist all the 7-inch ammunition in about forty-one and a-half minutes.

Hoists 5, 6, 19 and 20, assisted by 23 and 24, can hoist all 3-pdr. and 1-pdr. ammunition in about eighteen minutes.

Hoists 11, 12, 15 and 16, and 19 and 20, assisted by 23 and 24, can hoist all 3-inch, 3-pdr. and 1-pdr. in about twenty-three and one-half minutes.

About 10 per cent. of 7-inch shells will be stowed near the guns.

Hoists 1 and 2 for 3-inch only. Hoists 5, 6, 19, 20, 23 and 24 will be assisted by hoists 11, 12, 15 and 16, the ammunition being whipped or passed from main to upper deck.

Hoists 25 and 26 to hoist 3-inch ammunition only.

## WATERTIGHT COMPARTMENTS.

### CAPACITY OF DOUBLE-BOTTOM COMPARTMENTS BELOW WATERTIGHT LONGITUDINALS.

| Compt. | Gals. | Tons F.W. | Tons S.W. | Compt. | Gals. | Tons F.W. | Tons S.W. |
|---|---|---|---|---|---|---|---|
| A-94 | 12,970 | 48.2 | 49.54 | B-89 | 6,248 | 23.2 | 23.88 |
| A-95 | 16,912 | 62.8 | 64.60 | B-90 | 5,359 | 19.9 | 20.45 |
| A-96 | 18,139 | 67.4 | 69.28 | B-91 | 5,359 | 19.9 | 20.45 |
| A-97 | 14,677 | 54.5 | 56.05 | B-92 | 4,471 | 16.6 | 17.05 |
| A-98 | 18,041 | 67.0 | 68.88 | B-93 | 4,471 | 16.6 | 17.05 |
| A-99 | 24,234 | 90.0 | 92.54 | C-95 | 23,991 | 89.1 | 91.68 |
| B-80 | 19,441 | 72.2 | 74.28 | C-96 | 19,926 | 74.0 | 76.08 |
| B-81 | 16,614 | 61.7 | 63.48 | C-97 | 19,899 | 73.9 | 75.97 |
| B-82 | 23,588 | 87.6 | 90.08 | C-98 | 19,360 | 71.9 | 73.97 |
| B-83 | 20,384 | 75.7 | 77.85 | C-99 | 18,714 | 69.5 | 71.51 |
| B-84 | 17,071 | 63.4 | 65.20 | D-96 | 18,256 | 67.8 | 69.74 |
| B-85 | 24,018 | 89.2 | 91.74 | D-97 | 17,017 | 63.2 | 65.00 |
| B-86 | 20,681 | 76.8 | 78.97 | D-98 | 17,502 | 65.0 | 66.82 |
| B-87 | 17,234 | 64.0 | 65.82 | D-99 | 17,754 | 66.3 | 68.27 |
| B-88 | 6,248 | 23.2 | 23.88 | Total. | 468,579 | 1,740.6 | 1,790.11 |

### RESERVE-FEED TANKS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B-94 | 5,804 | 21.55 | 22.20 | B-97 | 4,982 | 18.50 | 19.06 |
| B-95 | 5,804 | 21.55 | 22.20 | B-98 | 4,151 | 15.42 | 15.88 |
| B-96 | 4,982 | 18.50 | 19.06 | B-99 | 4,151 | 15.42 | 15.88 |
| | | | | Total. | 29,874 | 110.94 | 114.28 |

### CAPACITIES OF TRIMMING TANKS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A-1 | 4,907 | 18.22 | 18.74 | D-10 | 14,848 | 55.13 | 56.71 |
| A-2 | 7,764 | 28.83 | 29.65 | D-11 | 10,352 | 38.44 | 39.54 |

CAPACITIES OF FRESH-WATER TANKS.

| *Tank.* | *Gals.* | *Tons.* | *Tank* | *Gals.* | *Tons.* |
|---|---|---|---|---|---|
| 22-23 inboard, 1 P. 1 S. | 1,517 | 5.66 | 98-99 C. L. of ship | 1,868 | 6.97 |
| 21-22 middle, 1 P. 1 S. | 937 | 3.50 | 37-38 gravity | 800 | 2.98 |
| 21-22 outboard, 1 P. 1 S. | 844 | 3.15 | 39-40 gravity | 800 | 2.98 |
| 22-23 outboard, 1 P. 1 S. | 1,754 | 6.54 | | | |
| 98-99 1 P. 1 S. | 2,040 | 7.61 | Total | 10,560 | 39.39 |

COFFERDAMS.

| | *Cubic feet.* | | *Cubic feet.* | | *Cubic feet.* |
|---|---|---|---|---|---|
| A-100 | 329 | A-127 | 352 | D-118 | 404 |
| A-112 | 188 | B-102 | 318 | D-108 | 874 |
| A-113 | 188 | B-103 | 318 | | |
| A-114 | 289 | C-104 | 342 | IN BUNKERS. | |
| A-115 | 289 | C-105 | 342 | | |
| A-116 | 390 | C-106 | 288 | | |
| A-117 | 390 | C-107 | 288 | B-104 | 316 |
| A-118 | 389 | D-109 | 296 | B-105 | 316 |
| A-119 | 389 | D-110 | 296 | B-106 | 341 |
| A-120 | 383 | D-111 | 375 | B-107 | 341 |
| A-121 | 383 | D-112 | 375 | B-108 | 370 |
| A-122 | 370 | D-113 | 394 | B-109 | 370 |
| A-123 | 370 | D-114 | 394 | B-110 | 370 |
| A-124 | 302 | D-115 | 635 | B-111 | 370 |
| A-125 | 302 | D-116 | 635 | B-112 | 398 |
| A-126 | 352 | D-117 | 404 | B-113 | 398 |

There are 314 watertight compartments, of which 217 are below the protective deck, and 97 above the protective deck. They are distributed as follows, viz:

On berth deck, 28 compartments; on protective decks, 69 compartments; on upper platform deck, 50 compartments; on lower platform deck, 31 compartments; in hold, 67 compartments; in inner bottom, 69 compartments.

Compartments A92 to A99, B66 to B99, C89 to C99, D90 to D99, all inclusive, are double-bottom compartments, of which the following are wing compartments under coal bunkers and outboard sides of boiler rooms, viz: A86 to A93, B66 to B79, B88 to B93, C89 to C94, D90 to D95, all inclusive; they form the upper double bottom, between the armor and the sixth longitudinal, which is watertight. The remaining double-bottom compartments are central compartments, extending from the sixth (watertight) longitudinal on one side to the sixth longitudinal on the other side of the keel and non-watertight through the central line.

Double-bottom compartments B94 to B99, inclusive, are fitted for reserve-feed tanks, and compartments B88 to B93, inclusive, A1, A2, D10 and D11 are trimming tanks. C95

and C96 are under the engine rooms. The tables on preceding page give the capacities and the uses of various compartments fitted for special purposes.

## GENERAL NOTES.

*Coaling Arrangements.*—The coal capacity is 2,415.1 tons, of which 718 tons are carried above the protective deck and 364 tons in the transverse bunkers at the ends of the boiler space. This is handled by means of tripod coaling booms; eight of these coaling booms are located on the main deck, four forward and four aft, and are arranged to lower coal bags through combination skylight and coaling hatches and companion and coaling hatches. Four coaling booms are located on upper deck, and are arranged to lower through combination skylight and coaling hatches and trunks. The coal is handled on the gun deck, where it is distributed to 24-inch scuttles and trunks leading to the various bunkers. The whips are operated by electric winches, two forward and two aft on main deck, and two on upper deck.

### CAPACITIES OF COAL BUNKERS.

#### Lower Bunkers.

| | *Cu ft.* | *Tons.* | | *Cu. ft.* | *Tons.* |
|---|---|---|---|---|---|
| B-7 | 4,967 | 115.5 | B-20 | 3,448 | 80.2 |
| B-8 | 5,619 | 130.7 | B-21 | 3,317 | 77.2 |
| B-9 | 2,335 | 54.3 | B-22 | 3,317 | 77.2 |
| B-10 | 2,335 | 54.3 | C-5 | 2,152 | 50.2 |
| B-11 | 2,290 | 53.3 | C-6 | 2,935 | 68.2 |
| B-12 | 2,290 | 53.3 | C-7 | 2,244 | 52.2 |
| B-13 | 3,102 | 72.2 | C-8 | 2,244 | 52.2 |
| B-14 | 3,102 | 72.2 | C-9 | 2,529 | 58.8 |
| B-15 | 3,437 | 79.9 | C-10 | 2,529 | 58.8 |
| B-16 | 3,437 | 79.9 | C-11 | 2,300 | 53.5 |
| B-17 | 3,455 | 80.4 | C-12 | 2,175 | 50.6 |
| B-18 | 3,455 | 80.4 | | | |
| B-19 | 3,448 | 80.2 | Below protective deck, | | 1,685.7 |

#### Above Protective Deck.

| | | | | | |
|---|---|---|---|---|---|
| B-118 | 2,692 | 62.6 | B-126 | 3,288 | 76.5 |
| B-119 | 2,692 | 62.6 | B-127 | 3,288 | 76.5 |
| B-120 | 3,024 | 70.3 | B-128 | 3,356 | 78.0 |
| B-121 | 3,024 | 70.3 | B-129 | 3,356 | 78.0 |
| B-122 | 3,324 | 77.3 | | | |
| B-123 | 3,324 | 77.3 | | | 729.4 |
| | | | Total, all bunkers, | | 2,415.1 tons. |

## VENTILATION.

The ventilation of the ship is on the plenum, or supply system, except in the special cases of sick bay, waterclosets, dynamo rooms and steering-engine rooms. The ventilation blowers are electrically driven and the general arrangement is in accordance with recent Navy practice. To avoid as far as possible the piercing of watertight bulkheads, the ventilating system is subdivided into a number of small systems. Forced ventilation is provided for all quarters, living spaces, passages, storerooms and magazines below the gun deck, also for all spaces over boilers and around magazines, and for all wash-rooms, closets and similar enclosures above the gun deck.

## FIRE PLUGS.

There are sixty-one fire plugs in the ship, distributed as follows, viz:

| | | | |
|---|---|---|---|
| Hold | 5 | Main deck | 12 |
| Lower platform | 4 | Upper deck | 6 |
| Upper platform | 4 | Bridge, forward | 1 |
| Berth deck | 12 | Bridge, aft | 1 |
| Gun deck | 16 | | 61 |

## MASTS AND SPARS.

There are two military masts. The fore mast is at frame 36, the main mast at frame 76. Each mast has an upper and a lower military top and a signal yard. The main mast has a lower searchlight platform, below the lower top. On the fore mast, just above the signal yard, is a lookout platform, fitted with guard rails and in communication with the bridge. The main mast is fitted with a small monkey gaff, and the wireless telegraph connections will be fitted on this mast.

**Heights:**

Above designed L. W. L., 24 feet 6 inches forward and aft.
24 feet 6 inches W. L. is 24 feet 4⅛ inches above base line.

**Masts, fore and main:**

| | |
|---|---|
| Truck light, top of, feet and inches | 131-09¼ |
| Ranging platform floor, top of (forward only), feet and inches | 114-02$\frac{1}{16}$ |
| Searchlight platform, feet and inches | 75-07⅛ |
| Lower searchlight platform (aft only), feet and inches | 42-07⅛ |

| | |
|---|---|
| Masts, fore and main: | |
| Upper top, floor (forward only), feet and inches | 64–07⅛ |
| Lower tops, floor, feet and inches | 54–07⅛ |
| Bridge at 38 center line (forward), feet and inches | 34–09½ |
| Flying bridge at 38 center line, feet and inches | 44–07½ |
| side, feet and inches | 43–09⅛ |
| After bridge at 74 center line, feet and inches | 34–06⅛ |
| side, feet and inches | 33–08⅛ |
| Top of waist plate at stem, feet and inches | 24–00 |
| beading at stern, feet and inches | 20–09½ |
| main deck planking at stem, feet and inches | 20–10 |
| stern, feet and inches | 20–04½ |
| flat armor deck, feet and inches | 3–00 |

## POWER WATERTIGHT DOORS.

There are forty-two doors and five armored hatches, which are operated by electrical power. They are of the long-arm system, similar to those installed on previous ships. They are so designed as to be operated on the spot by power or hand gear from either side of the bulkhead or deck. They can also be operated simultaneously by power from the emergency-control station located on forward bridge. Electrically-operated solenoid whistles are provided as a warning when doors are to be so closed. During any period of emergency operation any individual door or hatch can be operated by power or hand, and after such operation during the period of emergency operation the closing repeats itself automatically.

## DRAINAGE AND FLOODING SYSTEMS.

The main drain, 15½ inches inside diameter, is fitted on starboard side between the inner bottom and boiler and engine-room floors and has a suction in each engine and boiler room above inner bottom; the valve for each suction is operated from compartment which it drains and also in deck plates on berth deck. The main drain is connected directly with the main circulating pumps, and has an auxiliary connection to the construction and repair drainage manifold near each fire and bilge and auxiliary feed pump. These drainage manifolds are connected to steam engineering pump manifolds.

The secondary drain, 5½ inches diameter, is run on port

side throughout length of machinery spaces and is connected to each construction and repair drainage manifold above mentioned. Branches are led from the secondary drain to bilge wells located in after ends of boiler and engine compartments, those on port side leading directly into drain, and those on starboard side leading through the manifold suctions to bilges forward and abaft machinery spaces, to shaft alleys and double-bottom compartments, are led to the drainage manifolds. All valves on secondary drain are operated 30 inches above floor plates.

Double-bottom compartments under machinery spaces, except those used for reserve-feed water, are provided with means both for drainage and flooding; outside these spaces with mains for drainage only, except for those outboard of sixth longitudinal, where piping is to be fitted for either drainage or flooding. In general, compartments not provided with other means of drainage will be drained by means of hose led through doors or hatches.

The fire mains are of 6-inch copper pipe, sabined and run continuously through machinery spaces on each side of ship, directly under protective-deck beams. The port and starboard systems are cross connected at ends of machinery spaces, forming a circuit to which all fire and bilge pumps are connected direct. Risers from main are fitted to supply necessary plugs in each compartment above. Forward and aft of machinery spaces, throughout magazine spaces, a single main is led from the cross connection to supply risers and plugs in those localities. The fire main is also connected to the magazine-flooding system on upper platform. It has also by-pass connections to the flushing system, the full diameter of the latter.

The flushing system is 4-inch copper pipe, sabined and installed under gun-deck beams. This supplies salt water to all spaces throughout ship where required. On upper platform, forward, two separate motor-driven centrifugal pumps are provided for flushing and providing salt water for showers, washrooms, heads, etc.

The fresh-water service throughout the ship is provided by means of a gravity tank located on upper deck and of 1,600 gallons capacity. Two electrically-operated, reciprocating fresh-water pumps are provided, one aft and one forward, for general service of all tanks.

## BOATS.

The following table gives the number and sizes of the boats, with location of each and weight carried by each.

| | Men. | | Water and provisions. | | Weight of each boat, stores and men. | Location on bridge deck. | Frames. |
|---|---|---|---|---|---|---|---|
| | Each. | Total. | Each. | Total. | | | |
| | | | | | *Lbs.* | | |
| 1 50-ft. steam cutter | ... | 60 | ... | 600 | 19,680 | Starboard aft. | 52–63 |
| (40-ft. steam cutter temporarily fitted). | | | | | | | |
| 2 36-ft. steam cutters | 53 | 106 | 530 | 1,060 | 16,961 each | P. and S. aft. | 53–62 |
| 1 36-ft. launch | ... | 78 | ... | 780 | 9,953½ | Port aft. | 53–62 |
| 3 33-ft. launches | 64 | 192 | 640 | 1,920 | 8,470½ each | 1 starb. aft. | 54–63 |
| | | | | | | 2 port aft. | 53–63 |
| 5 30-ft. cutters* | 45 | 225 | 450 | 2,250 | 5,624½ each | 1 starb. aft. | 54–62 |
| | | | | | | 2 port aft. | 54–62 |
| 1 30-ft. barge (davits, main deck) | ... | 37 | ... | 370 | 5,200 | Starboard aft. | 96–103 |
| 2 30-ft. whale boats (davits, main deck) | 29 | 56 | 280 | 560 | 4,802½ each | 1 port aft. | 76–84 |
| | | | | | | 1 starb. aft. | |
| 1 30-ft. whale boat (gig, main deck) | ... | 20 | ... | 200 | 4,471½ | Port aft. | 96–103 |
| 2 20-ft. dinghies | 12 | 24 | 120 | 240 | 2,079½ each | 1 starb. aft. | 65–71 |
| | | | | | | 1 port aft. | |
| 1 16-ft. dinghy | ... | 5 | ... | 50 | 1,324½ | Port aft. | 65–71 |
| 1 14-ft. dinghy | ... | 4 | ... | 40 | 1,029½ | Starboard aft. | 67–71 |

* The sea position for two of these cutters is on davits, main deck, between frames 30 and 38.

## ANCHOR WINDLASS.

There is one American Ship Windlass Co.'s steam windlass with four wildcats, capable of hoisting two 17,600-pound anchors at the same time. It is of the worm-gear type, operated by a vertical shaft, which is connected to the engine on gun deck by bevel gears. The engine is designed to work at 150 pounds steam pressure.

## ELECTRIC PLANT.

There are eight 100-kilowatt generating sets of 125 volts pressure at the terminals. The generators were supplied by the General Electric Co., and are of the direct-current compound-wound, multipolar type. The wiring is on the two-

wire system. These eight machines are placed in two dynamo rooms, four in each room. The dynamo rooms are situated under the protective deck, one just forward of the boiler compartments, the other just abaft the boiler compartments, on the upper platform. Steam is supplied to the generators directly from the auxiliary steam pipe; two dynamo condensers, one in a pocket just under each dynamo room, are provided for taking the exhaust steam of only the dynamos; these condensers are so connected that the dynamo exhaust, forward or aft, may be led into either dynamo condenser or into either auxiliary condenser in the engine room.

*Dynamo Engines.*—The engines are of the vertical, cross-compound, General Electric Co.'s type; all the working parts are enclosed and lubricated under pressure; the introduction of oil into the cylinders is guarded against by fitting a top plate on the enclosing covering, with an oil wiper around valve stems and stuffing box around piston rod, in which are soft-packed stuffing boxes for the rods and valve stems to work through.

| | |
|---|---|
| Dynamo engines, 100-kilowatt, number of | 8 |
| Diameter of cylinders, H.P., inches | 10 |
| L.P., inches | 18 |
| Stroke, inches | 10 |
| Diameter of piston rods, H.P., inches | 2.25 |
| L.P., inches | 2.25 |
| Revolutions per minute, full load | 350 |

*Motors.*—All the auxiliary machinery outside the engine and firerooms, except the ice machine, the anchor engine, the forced-draft blowers and the steering engine and evaporator pumps, is driven by electric motors. The following is a list of the motors installed, viz:

| *No.* | *H.P.* | *Winding.* | *Use.* |
|---|---|---|---|
| 42 | 1 | Comp. | For operating power watertight doors. |
| 5 | 1 | Comp. | For operating power watertight hatches. |
| 2 | 50 | Series | Hoisting motors for boat cranes. |
| 2 | 30 | Series | Rotating motors for boat cranes. |
| 6 | 30 | Comp. | For deck winches. |
| 26 | 3 | Shunt | For endless-chain ammunition hoists. |
| 4 | 3.5 | Shunt | For ammunition whips. |

| *No.* | *H.P.* | *Winding.* | *Use.* |
|---|---|---|---|
| 4 | 4 | Shunt | For endless-chain ammunition conveyors. |
| 4 | 25 | Shunt | For turning 12-inch turrets. |
| 8 | 15 | Shunt | For turning 8-inch turrets. |
| 32 | Var. | ..... | For ventilating fans. |
| 1 | 6 | Shunt | For operating steam-laundry machinery. |
| 2 | 2 | Shunt | For operating fresh-water pumps. |
| 2 | 5 | Shunt | For operating flushing pumps for head. |
| 2 | 1.5 | Shunt | For drainage pump for firemen's washroom. |

In addition to the above there are the following:

8 portable ventilating sets of ¼ H.P. each.

58 desk-and-bracket fans of $\frac{1}{12}$ H.P. each.

8 bracket fans of ⅙ H.P. each.

*Motor Generators.—Turret-Control System.*—The turrets are controlled on the Ward-Leonard system. The current for driving the turret-training motors and the gun-elevating motors, both 12-inch and 8-inch, is furnished by motor generators in each turret, which in turn are driven by current from the main generators. With this arrangement one main generator may be used to furnish current for both turret power and lighting at the same time, without having the flickering of lights due to variation in the load when working the turrets.

For each 12-inch turret there is provided a 25-kilowatt motor generator for training horizontal train turning, and for each 12-inch gun, an 8-kilowatt motor generator for elevating. For each 8-inch turret there is provided a 15-kilowatt motor generator for training horizontal train turning, and for each 8-inch gun a 3½-kilowatt for elevating.

Speed regulation is obtained by varying the field of the generator and motor generator up to a certain limit, and beyond that by varying the field of the training or elevating motor.

*Lighting Output.*—The output for lighting supplies 1,100 16-candlepower incandescent lamps; an additional 100 lamps will probably be provided; also ten 3-ampere arc lights; two 60-inch searchlights (of about 42,000 candlepower each) and four 30-inch searchlights (of about 20,000 candlepower each); two night-signaling sets, two truck lights; two diving lanterns, with eight 150-candlepower lamps.

*System of Distribution.*—The wiring is on the two-wire feeder system. In each dynamo room there is a generator switchboard to which the four machines may be connected. On the opposite side of the dynamo room, in a separate watertight compartment, there is a distribution board. The forward distribution board feeds all circuits leading to outlets forward of the amidship section of the ship; the after distribution board feeds all circuits leading to outlets abaft the amidship section.

Either distribution board may be connected with either generator switchboard; thus, any generator may be connected with any circuit, lighting, power or turret.

The following circuits are provided with feeders from each distribution board and with double-pole throw-over switches, allowing the use of either feeder; this duplicates the feeders to these circuits, viz:

All lighting circuits in firerooms.

All lighting circuits in engine rooms.

Each circuit feeding motor generator.

Each circuit feeding turret-ammunition hoist and training motors and miscellaneous turret power.

*Turret-Hoist Indicators.*—A 16-candlepower incandescent-light signal is provided for signaling from the handling room when the ammunition-lift car is loaded and ready for hoisting.

A 16-candlepower incandescent-light signal, automatic in operation, is provided for indicating when the car of the turret-ammunition lift arrives within 42 inches of the extreme lower position. These lamps are, one green and one red.

*Interior Communication.*—A complete central-station system of telephones is installed. There are thirty-five telephones altogether, including two in central station. There are 139 leads of voice tube.

The telephones are a special type of loud-speaking instrument, made by the Cory Company. With these instruments three wires are required for each instrument instead of six wires, as required by the Bell system. Those instruments

located in stations where they will be subject to exposure, moisture or rough usage, or where there is a great amount of noise, are of watertight type. There are two ear pieces which encircle the ear and exclude external sounds. The instruments are said to work very satisfactorily, even in exposed places in a high wind.

*Warning Signals for Watertight Doors.*—A system of whistles, operated by solenoids, is installed to give warning of the closing of the power watertight doors. The system for closing watertight doors and hatches is known as the "Long-arm Door System," the doors being operated by electric motors.

*Additional Interior Communication.*—The usual installation of call bells, fire alarm system, general alarm gongs, boat hour gongs, shaft indicators, steering telegraphs and indicators, engine-revolution telegraphs and indicators, helm indicators, electric gong, battery-control and torpedo-firing apparatus.

## PROPELLING MACHINERY.

The propelling engines are right and left hand, placed in watertight compartments abreast each other, separated by middle-line bulkhead. There are two 4-cylinder triple-expansion engines, vertical, inverted cylinders, direct action, each with high-pressure cylinder 32½ inches, intermediate-pressure cylinder 53 inches and two low-pressure cylinders 61 inches, the stroke of all being 48 inches. The engines are of Bureau of Steam Engineering design. They are designed to develop 16,500 horsepower when making about 120 revolutions for a speed of 18 knots per hour, the maximum piston speed in no case to exceed 1,000 feet per minute, and no live steam to be used in the receiver in any full-power trial. They are arranged for *outboard-turning* propellers when going ahead.

The order of the cylinders, beginning forward, is: forward low pressure, high pressure, intermediate pressure and after low pressure. The forward low and high-pressure cranks are opposite, and also the intermediate and after low-pressure

cranks, the second pair being at right angles with the first, the sequence of cranks thus being: high pressure, intermediate pressure, forward low pressure and after low pressure. The cylinder castings are of cast-iron with cast-iron liners in the barrels. The cylinder liners make steam-tight joints with the castings both at the top and the bottom, and the space between the liners and casing forms the steam jacket for the cylinder barrel. All cylinder covers except the H.P.'s are also jacketed.

The engine framings are of forged-steel cylindrical columns, twelve in all, supporting the cylinder crosshead guides, etc. They are flanged top and bottom and secured to the cylinders and bed plates, and have enlarged facings for the athwartship and longitudinal tie-rod braces. The columns are tied fore and aft horizontally by heavy cast-steel eye braces of forged steel and by diagonal rods, and are also strengthened athwartship by forged steel X-frames from top to bottom of columns. The bed plates are of cast steel supported on the keelson plates worked in the hull. The forward L.P. and H.P. engines are secured together by flanges on the sides, as are also the after L.P. and M.P. cylinders. The forward and after pair of cylinders have removable chocks fitted to lugs on H.P. cylinder casing to prevent side motion while allowing expansion in a vertical and fore-and-aft direction. The pairs of cylinders of one engine are secured across to those of the other engines by tie rods through the middle-line bulkhead and also by tie rods through the forward and after engine-room bulkheads.

The engine bed plates are all cast steel and are made in three sections for each engine, bolted together at flanges. Each section carries two main bearings. The bed plates are secured to the keelson plates worked in the hull. The H.P. cylinder has one piston valve. Each of the other cylinders has two, all equal in diameter. The L.P. and M.P. valves differ only in length. The main valves are all of single-ported piston type, built up with top and bottom cast-steel heads and a steel-tube distance piece between the heads. Each

head is fitted with a cast-iron packing piece and cast-steel follower. A balance piston fitted at the top of each steam valve and working in a small cylinder in top of valve-chest cover is provided to relieve a part of weight of valve gear. The valve gear is of the Stephenson type with double-bar links, fitted with adjustable cut-off blocks by which cut-off may be adjusted between the limits of .5 and .76 stroke. The valve gears of each engine are handled by a vertical steam-reversing engine with oil-controlling cylinder secured to the H.P. cylinder case. A reversing shaft is carried in bearing brackets secured to the front of the engine columns, and provided with an arm for each link, fitted with adjustable cut-off block and two arms for reversing-engine connecting rods. Reversing engine is controlled by a lever at the working platform. An 11-inch balanced throttle valve is provided for each engine and operated by a hand wheel at the working platform.

DATA FOR CYLINDERS.

| | |
|---|---|
| 1 H.P., diameter, inches | 32½ |
| 1 I.P., diameter, inches | 53 |
| 2 L.P., diameter, inches | 61 |
| Stroke of all pistons, inches | 48 |
| Volume swept by H.P. piston per stroke, cubic feet | 22,470 |
| I.P. piston per stroke, cubic feet | 60,709 |
| L.P. piston per stroke, cubic feet | 80,604 |
| Ratio of area I.P. to H.P. piston | 2.659 to 1 |
| H.P. to L.P. piston | 7.046 to 1 |
| Cylinder walls, thickness, H.P., I.P. and L.P., inches | 1½, 1 7/16, 5/8 |
| liners, thickness, H.P., I.P. and L.P., inches | 1½, 1 5/16, 1½ |
| Valve-chest liners, thickness, H.P., I.P. and L.P., inches | 1½, 1½, 1½ |
| Jacket space, inch | ¾ |

Pistons are of conical form. H.P. piston is of cast iron, comparatively heavy for balancing; the I.P. and L.P. pistons are of cast steel. The piston rings are of cast iron. The H.P. and M.P. have each one ring with two packing grooves; where the ring is cut there is on the inside of each end of the ring a square shoulder ⅜ inch by 1 inch wide, over which is fitted a mortised-steel tie piece uniting the ends, thereby making the ring practically solid, but yet adjustable for wear. The L.P. have two rings, each in six sections, jointed as above.

All pistons are fitted with forged-steel followers, secured to the pistons by studs having square shoulders to prevent turning when they wear. They are ground true and burnished; each end is tapered, one for the reception of the piston and the other for the crosshead.

A thread is cut on the upper end of each piston for about an inch and a-half to receive a nut for use in handling the piston.

Piston rods are of annealed steel and tapered at each end to fit the piston or crossheads.

*Crossheads.*—Crossheads are of class "A" nickel-steel forgings, and carry a cast-steel slipper lined with white metal on the sliding face. The crosshead pins have tapered axial holes, the surface of the pins being flattened on each side, thereby reducing the bearing at the sides of the brasses and leaving a space for lubricant.

*Crosshead Slippers.*—The slippers are of cast steel, are secured to the crosshead by six 1½-inch tap bolts, and are lined with white metal.

*Crosshead Guides.*—The ahead guides are of cast iron, bolted at top and bottom to the strongbacks of the engine columns, and stiffened by webs on the back. The backing guides are of cast steel bolted to the ahead guides, with liners between to permit adjustment to wear.

Connecting rods are of the same material as the piston rods, and have axial holes, and forked at the upper end to carry the crosshead brasses, and the lower end is faced to receive the crank-pin brasses. The brasses are secured by a forged-steel cap and bolts.

The eccentrics are in two parts, are bolted together and keyed to raised seatings on the crank shaft, the ahead eccentrics being arranged for slight adjustment by means of a slot of greater width than the key, which permits their being shifted radially.

The eccentric straps are of composition lined with white metal. They are in halves, fitted with distance pieces and bolted together.

## PROPELLERS.

There are two three-blade propellers; both are outward-turning for ahead motion.

The blades and the hub are of manganese-bronze. The hub is fitted on the tapered end of the shaft and held in place by longitudinal keys and a nut. The blades fit in recesses on the hub; the bolt holes are elongated to permit adjusting the pitch of the blades.

The blades, after casting, were ground and burnished, and the propellers swung between centers on a mandrel, and accurately balanced by removing metal from the heavier blades.

## SHAFTING AND SHAFT BEARINGS.

The shafting is of class "A" forgings in six sections, viz: two sections of crank shaft, thrust, line, stern-tube and propeller shafts. The stern-tube section is coupled to the line shaft so as to permit withdrawal from stern tube. All shafting is hollow. The stern-tube shafts, which cannot be readily examined, are protected against the action of sea water by brass casing, shrunk on. Both the stern-tube and propeller shafts are fitted with heavy brass journals at the stern-tube and strut bearings.

All shaft couplings are of standard flange type, forged to the shafts, except the forward coupling of the stern-tube shaft and the outboard coupling connecting the stern-tube and propeller shafts. The former consists of a forged-steel collar secured to a raised seating on the shaft by keys, while the outboard coupling consists of a forged-steel sleeve, taper bored from each end to the center, for receiving the tapered shaft end. The sleeve is secured to the shaft end by four keys and two collars. The sleeve couplings are covered by a water-tight cast-composition casing. the space between the casing and coupling being filled with tallow and rosin.

There are six main bearings for each crank shaft, two steady bearings for each thrust shaft, two spring bearings for each line shaft, two stern-tube bearings for each stern-tube shaft and one strut bearing for each propeller shaft.

There is one thrust bearing for main engine, of the ordinary horseshoe type, consisting of cast-iron pedestal bolted to cast-iron plate which is riveted to the foundation built in the hull structure. The lower part of the pedestal forms an oil trough in which the lower part of the thrust collars turn, the trough being fitted with a water-circulating coil for cooling the oil.

There are thirteen horseshoes of cast steel, made hollow for the circulation of cooling water, and lined with white metal on the bearing surface, each horseshoe being independently adjusted fore-and-aft by clamp nuts on screwed steel side.

The turning gear for each engine consists of a two-cylinder engine driving a worm gearing that meshes in the worm wheel keyed to the after crank-shaft coupling. There is in addition a ratchet attachment for turning by hand.

## MAIN CONDENSERS.

There is one main condenser, located on the outboard side of each engine room; they are of horizontal, cylindrical, surface-condensing type. The shell is made of boiler plate; composition heads, and tube sheets of Muntz metal, the tubes and ferrules of Admiralty metal and are not tinned. The forward head of each condenser is fitted with a butterfly valve, so that the circulating water can be diverted overboard without going through the condenser tubes. Zinc plates are placed on the inside of each manhole plate. The shell is lagged with cowhair felt and covered with galvanized sheet steel.

| | |
|---|---|
| Diameter of shell, feet and inches | 6–07 |
| Thickness of shell, inch | 00⅝ |
| Length over all, feet and inches | 15–04½ |
| Outside diameter, tubes, inch | 00⅝ |
| Thickness | No. 16 B. W. G. |
| Length between the tube sheets, feet | 13 |
| Number tubes in condenser | 4,838 |
| Cooling surface, each, square feet | 10,375 |

## PUMPS.

*Main Air Pumps.*—A main air pump is provided for each main condenser. They are of the Fore River twin-cylinder, vertical-beam, single-acting type.

| | |
|---|---|
| Diameter of steam cylinders (two), inches | 12½ |
| pump cylinders (two), inches | 30 |
| Stroke, inches | 20 |

*Main Circulating Pumps.*—One centrifugal, double-inlet, circulating pump, driven by a compound engine, is furnished for each main condenser. Each pump has a capacity of 12,000 gallons of water per minute at about 265 revolutions. The pumps are arranged to draw from the sea, the main drain, and from the engine-room bilge, and discharge through the condenser or directly overboard, through the by-pass in the inlet and outlet condenser head, to the overboard delivery. The suction valves of these pumps are so interlocked that the sea-valve and the bilge or drain valves cannot be opened at the same time.

| | |
|---|---|
| Diameter of steam cylinders, H.P., inches | 10 |
| L.P., inches | 20 |
| Stroke, inches | 10 |
| Diameter of pump runner, inches | 42 |
| inlet nozzle, inches | 18½ |
| outlet nozzle, inches | 21 |

*Feed Pumps.*—There are four main feed pumps, of the Fore River, simplex, vertical, double-acting, piston plunger type, two in each engine room. They are arranged to draw water from the feed and filter tanks, and discharge to the main feed line direct or through the feed-water heater, and then into the main feed line.

Six auxiliary feed pumps, of the same type as the above, are located one in each fireroom. They have suctions from the feed and filter tanks, the sea, the boiler blowpipes, and the drainage manifolds in their own compartment, and discharge into the auxiliary feed line, overboard and into the fire main.

| | *Main Feed Pumps.* | *Aux. Feed Pumps.* |
|---|---|---|
| Diameter of steam cylinger, inches | 16 | 14 |
| water cylinder, inches | 9½ | 8 |
| Stroke, inches | 18 | 12 |

*Feed Supply Pumps.*—In each engine room there is one Fore River, simplex, vertical, double-acting, feed supply pump, having suction connections from the reserve-feed tanks in the

double bottoms, and the filling pipes from the ship's side. These pumps discharge into the feed and filter tanks and into the reserve-feed tanks.

| | |
|---|---|
| Diameter of steam cylinder, inches | 6 |
| water cylinder, inches | 6 |
| Stroke, inches | 8 |

*Distiller Circulating Pump.*—There is one distiller circulating pump in the starboard engine room, 12 inches by 14 inches by 12 inches, vertical, simplex, piston, Fore River type. This pump has a sea suction and discharges through the distillers overboard or into the flushing main.

*Fire and Bilge Pumps.*—One fire and bilge pump of the Fore River, simplex, vertical, double-acting type, is located in each engine room. These pumps draw water from the sea, the drainage system and from the bilges in their own compartment, and discharge into the fire main or overboard.

| | |
|---|---|
| Diameter of steam cylinder, inches | 12 |
| water cylinder, inches | 10 |
| Stroke, inches | 12 |

*Feed and Filter Tanks.*—There is located in each engine room one combined feed and filter tank of 5,500 gallons capacity. The filter box is built in the forward upper end of the tank. It consists of three separate compartments, each filled with the filtering material, through which the water from the main and auxiliary air pumps discharge passes successively before entering the feed tank.

*Feed-Water Heaters.*—A vertical, cylindrical feed-water heater is located in each engine room on the discharge side of the main feed pumps. The heating agency is exhaust steam from the auxiliary exhaust line, which enters the shell at the top, circulates around the tubes and drains at the bottom to the main or auxiliary condensers. The feed water passes through the tubes, from bottom to top. A slight back pressure is kept in the auxiliary exhaust lines, for properly heating the feed water, by adjustable spring-relief valves at the connections to the condensers.

| | |
|---|---|
| Diameter of shell, inside, feet and inches | 2–05¼ |
| Length over all, feet and inches | 10–04 |
| Tubes, number in one heater | 683 |
| diameter, outside, inch | 00⅝ |
| thickness, No. 16 B.W.G., inch | 0.065 |
| length between tube sheets, feet and inches | 7–05 |
| Heating surface, each heater, square feet | 829 |

*Auxiliary Condensers.*—There are four auxiliary condensers, one in each engine room, and one for each dynamo room. They are of the Fore River surface-condensing type, with combined air and circulating pump, of the Fore River horizontal, simplex type, attached to and under the condenser.

| | *Engine room.* | *Dynamo room.* |
|---|---|---|
| Diameter of shell inside, feet and inches | 2–01¼ | 2–08¼ |
| Length over all, feet and inches | 8–08½ | 9–00½ |
| Tubes, number, each | 458 | 782 |
| diameter, outside, inch | 00⅝ | 00⅝ |
| thickness, No. 16 B. W. G., inch | 0.065 | 0.065 |
| length between tube sheets, feet and inches | 7–04 | 7–07 |
| Cooling surface, square feet, each | 550.8 | 970.3 |

*Auxiliary Air and Circulating Pumps.*—

| | | |
|---|---|---|
| Diameter of steam cylinder, inches | 8 | 10 |
| air cylinder, inches | 10 | 12 |
| water cylinder, inches | 10 | 12 |
| Stroke, inches | 12 | 12 |

*Forced-Draft Blowers.*—Twelve Sturtevant blowers, located two in each boiler compartment above the boilers, supply the forced draft. The blowers deliver directly into the firerooms, the closed-fireroom system being used. The engines are two-cylinder, upright and double.

| | |
|---|---|
| Steam cylinders, diameter, inches | 6 |
| Stroke, inches | 5 |
| Fan, diameter, inches | 66 |

## ASH HOISTS.

For the removal of ashes the ventilator in each fireroom is fitted with angle guide strips to facilitate the hoisting of the ash buckets through same, and thence by trolley to the chutes at the ship's side. The hoisting is done by six Williamson

Brothers 4½ by 4½-inch reversible ash-hoist engines, located in the fireroom hatches.

### DISTILLING APPARATUS.

The distilling apparatus is on the berth deck just forward of the engine hatches. It consists of three evaporators, of the horizontal straight-tube type, two vertical distillers, located in a trunk above the evaporators, and the necessary accessories. The designed capacity of the plant was 16,500 gallons of water per twenty-four hours, which requirement was most successfully met when tested.

| | *Evaporators.* | *Distillers.* |
|---|---|---|
| Diameter of shell, internal, feet and inches | 5-05 | 0-18 |
| Length over all, feet and inches | 7-06¼ | 6-02¼ |
| Tubes, number, each | 30 | 223 |
| diameter, outside, inches | 02 | 00⅝ |
| thickness, No. 12 and 16 B. W. G., inch | 00.109 | 00.065 |
| length between tube sheets, feet and inches | 5-10¼ | 4-06⅝ |
| heating surface, square feet | 275 | 165 |
| Capacity each, gallons per 24 hours | 5,500 | 8,250 |

TEST OF DISTILLING APPARATUS U. S. S. VERMONT, JAN. 4, 1907.

| Time | Steam pressure, pounds. | | | Vapor pressure, pounds. | | | Distilled water gal's per 5 min. | Injection water, temp. of | Distilled water, temp. of |
|---|---|---|---|---|---|---|---|---|---|
| | Coil 1. | Coil 2. | Coil 3. | Coil 1. | Coil 2. | Coil 3. | | | |
| 10·30 | 30 | 30 | 25 | 5 | 5 | 5 | ... | ... | ... |
| 11·00 | 30 | 27 | 22 | 4 | 4 | 4·75 | ... | ... | ... |
| 11·30 | 45 | 40 | 37 | 4·5 | 5 | 4·75 | ... | ... | 75 |
| 11·35 | 45 | 45 | 45 | 5 | 5 | 5 | 74 | .. | ... |
| 11·45 | 45 | 45 | 37 | 1·5 | 2 | 2.75 | 61 | ... | ... |
| 12·15 | 50 | 50 | 47 | 2 | 2.75 | 4·5 | 70 | ... | 78 |
| 12·55 | 50 | 50 | 45 | 2 | 3 | 3·5 | 70 | ... | ... |
| 1·30 | 45 | 45 | 40 | 1·5 | 2 | 4 | 71 | ... | ... |
| 1·55 | 50 | 47 | 45 | 1 | 1.5 | 3·75 | 70 | ... | 70 |
| Av'g. | 47.5 | 47.0 | 43.1 | 2.16 | 2.7 | 4.0 | 62.16 | 58.0 | 74.0 |

Gallons of water distilled per rate per 24 hours, 196.30.
Pounds of water distilled per square foot of H.S. per hour, 8.26.
Pounds of water distilled per square foot of C.S. per hour, 20.6.

NOTES.—
Designed capacity = 16,500 gallons per 24 hours.
Equivalent per hour = 687.5 gallons. (About 11.5 gallons per minute.)
Plant consists of three evaporators and two distillers.
Total H.S. = 825 square feet.
Total C.S. = 330.98 square feet.

## REFRIGERATING APPARATUS.

### U. S. S. "VERMONT"—TESTS OF 2-TON ALLEN DENSE-AIR ICE MACHINES No. 199, No 206.

| Ice machine number. | Time. | Pressures, in pounds. | | | Revolution per minute. | Temperatures, degrees Fahrenheit. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Refrigerator rooms. | | | | | Sea water. | Atmosphere. | Scuttlebutt. | |
| | | Steam. | Compressor cylinder. | Expander cylinder. | | Crew. | Junior and warrant officers. | Ward-room officers. | Admiral and Captain. | Air lock. | | | Forward. | Aft. |
| Ice Machine No. 199. January 24, 1907. | *a. m.* | | | | | | | | | | | | | |
| | 8·00 | 96 | ... | ... | 110 | 53 | 50 | 58 | 54 | 56 | 36 | 56 | 36 | 36 |
| | 8·30 | ... | 200 | 48 | 104 | ... | ... | ... | ... | ... | 36 | ... | ... | ... |
| | 9·00 | 120 | 225 | 65 | 108 | ... | ... | ... | ... | ... | 36 | 60 | 34 | 35 |
| | 10·00 | 92 | 250 | 72 | 104 | 50 | 45 | 52 | 46 | 56 | 36 | 60 | 34 | 35 |
| | 10·30 | 105 | 250 | 72 | 116 | ... | ... | ... | ... | ... | 36 | 61 | ... | ... |
| | 11·00 | 120 | 250 | 72 | 106 | 44 | 37 | 45 | 37 | 55 | 36 | 60 | 34 | 35 |
| | 11·30 | 122 | 250 | 72 | 114 | ... | ... | ... | ... | ... | 36 | 62 | ... | ... |
| | 12·00 | 122 | 250 | 72 | 112 | 34 | 26 | 33 | 26 | 52 | 36 | 61 | 34 | 34 |
| | *p. m.* | | | | | | | | | | | | | |
| | 12·30 | 122 | 242 | 70 | 111 | ... | ... | ... | ... | ... | 36 | 61 | ... | ... |
| | 1·00 | 122 | 260 | 75 | 107 | 22 | 19 | 23 | 20 | 49 | 36 | 63 | 34 | 34 |
| | 1·30 | 122 | 253 | 73 | 106 | ... | ... | ... | ... | ... | 36 | 63 | ... | ... |
| | 2·00 | 122 | 255 | 73 | 111 | 12 | 13 | 23 | 13 | 46 | 36 | 56 | 34 | 34 |
| | 2·30 | 121 | 250 | 72 | 112 | ... | ... | ... | ... | ... | 36 | 57 | ... | ... |
| | 3·00 | 122 | 247 | 70 | 114 | 14 | 9 | 14 | 10 | 45 | 36 | 58 | 34 | 34 |
| | 3·30 | 120 | 255 | 72 | 112 | ... | ... | ... | ... | ... | 36 | 56 | ... | ... |
| | 4·00 | 120 | 255 | 72 | 112 | 10 | 8 | 11 | 7 | 43 | 36 | 65 | 33 | 33 |
| Ice Machine No. 206. January 25, 1907. | *a. m.* | | | | | | | | | | | | | |
| | 10·00 | 127 | ... | ... | 130 | 40 | 38 | 40 | 39 | 38 | 31 | 56 | 38 | 38 |
| | 10·30 | 122 | 95 | 23 | 120 | ... | ... | ... | ... | ... | 31 | 56 | ... | ... |
| | 11·00 | 121 | 165 | 43 | 116 | 38 | 33 | 39 | 36 | 38 | 31 | 61 | 38 | 38 |
| | 11·30 | 122 | 220 | 62 | 108 | ... | ... | ... | ... | ... | 31 | 60 | ... | ... |
| | 12·00 | 122 | 253 | 73 | 111 | 35 | 31 | 36 | 33 | 39 | 31 | 63 | 38 | 38 |
| | *p. m.* | | | | | | | | | | | | | |
| | 12·30 | 121 | 257 | 75 | 110 | ... | ... | ... | ... | ... | 31 | 64 | ... | ... |
| | 1·00 | 122 | 255 | 75 | 108 | 30 | 25 | 30 | 27 | 37 | 31 | 65 | 37 | 36 |
| | 1·30 | 122 | 250 | 72 | 109 | ... | ... | ... | ... | ... | 31 | 61 | ... | ... |
| | 2·00 | 122 | 250 | 72 | 110 | 25 | 19 | 24 | 21 | 36 | 31 | 63 | 34 | 33 |
| | 2·30 | 122 | 265 | 76 | 108 | ... | ... | ... | ... | ... | 31 | 62 | ... | ... |
| | 3·00 | 122 | 255 | 74 | 112 | 12 | 11 | 15 | 13 | 34 | 31 | 63 | 34 | 33 |
| | 3·30 | 121 | 250 | 72 | 113 | ... | ... | ... | ... | .. | 31 | 65 | ... | ... |
| | 4·00 | 120 | 250 | 73 | 112 | 12 | 7 | 9 | 8 | 32 | 31 | 65 | 34 | 33 |

Steam cylinder 9¼ inches. Compressor cylinder 7 inches. Expander cylinder 5¼ inches × 13 inches stroke. No. 199—3 cans ice at 11 ; ice tanks cut off at 11·12 ; 6 cans at 12 ; all cans at 2 P. M.

No. 206—3 cans ice at 1 ; all frozen at 2 P. M. (135 pounds).

NOTES.—Plant consists of two-ton ice machines and accessories. Each machine run independently on all circuits, beginning with atmospheric conditions throughout plant and continued until demonstrated that temperatures of refrigerating rooms and scuttlebutts were lowering uniformly and a full tank (135 pounds) of ice frozen.

This plant consists of two 2-ton horizontal Allen dense-air ice machines of the latest design and naval practice, supplying cold air to the cold-storage rooms, ice-making tank and the scuttlebutts. The official test of this plant showed highly satisfactory results.

## GENERAL WORKSHOP.

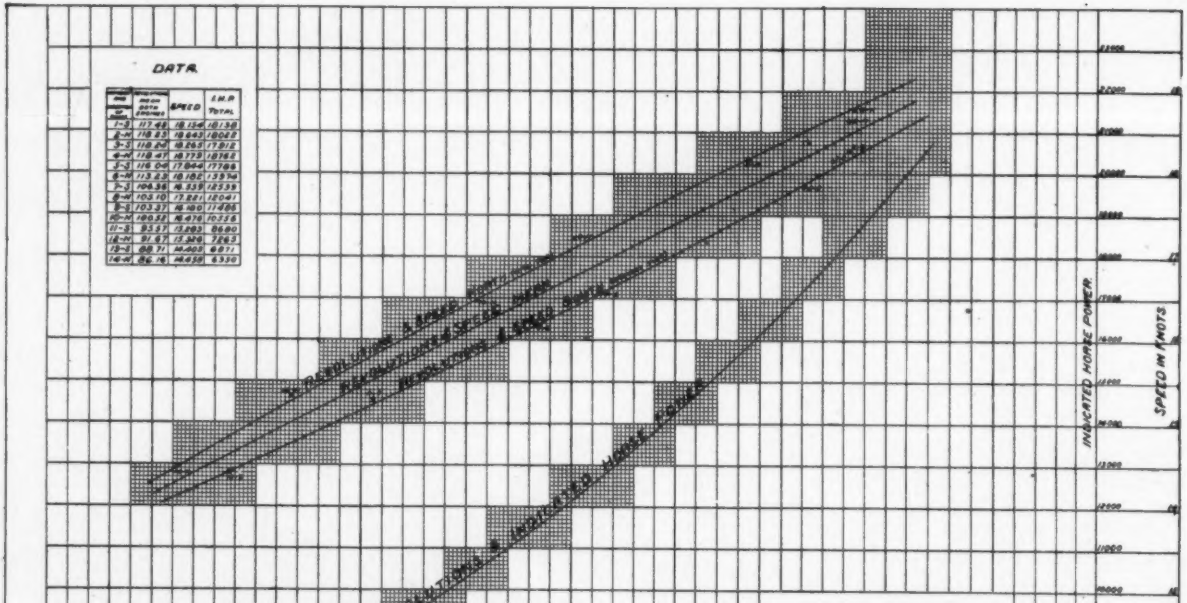
Located on the berth deck, between the engine hatches, is the general workshop. The tools are driven by a 10-horse-power motor. The following tools are installed: One 28 by 48-inch and one 14-inch lathe; one milling machine; one shaper; one 31-inch drill press; one 16-inch sensitive drill; one double-wheel emery grinder; one punch and shear; one grindstone; and bench vises.

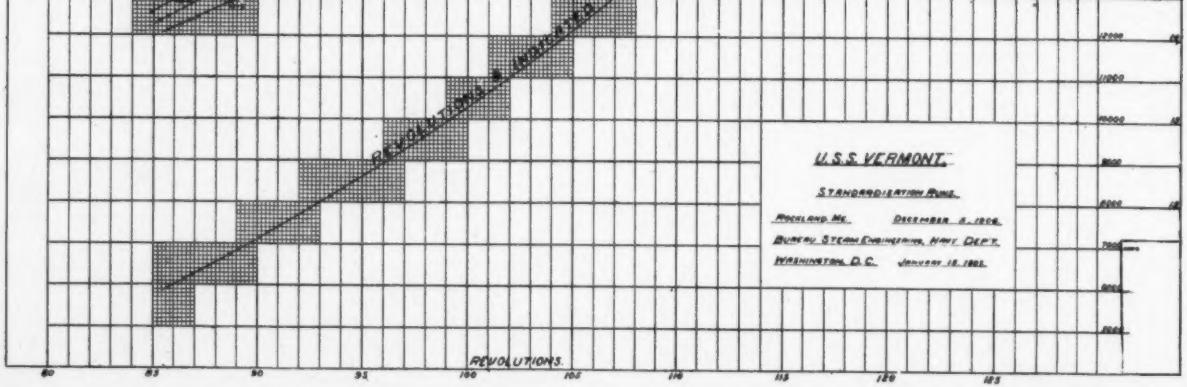
An air compressor is installed in the port engine room for running pneumatic tools.

## SCREW PROPELLERS.

The two propellers are of manganese-bronze and turn outboard when going ahead. They have three blades, and are designed as true screws. The surfaces of the blades are ground smooth with an emery wheel and edges filed sharp, the hub and blades are cast separate, the latter being bolted to the hubs by seven tap bolts each. The bolt holes in the palm of the blades are elliptical to permit of adjusting the pitch. After the pitch has been set the blades are secured against turning by composition chock pieces fitted in the space between the bolts and edges of the elliptical holes.

| | |
|---|---|
| Diameter of propeller, feet and inches | 17-09 |
| hub, feet and inches | 4-06 |
| Pitch, feet and inches | 18-00 |
| ratio to diameter | 1.014 |
| variable between, feet | 17 and 19 |
| Helicoidal (developed) area, square feet | 90.57 |
| Projected area, square feet | 77.88 |
| Disc area, square feet | 247.45 |


DATA
SPEED
I.H.P. TOTAL
INDICATED HORSE POWER
SPEED IN KNOTS


REVOLUTIONS & INDICATED
U.S.S. VERMONT.
STANDARDIZATION RUNS.
ROCKLAND ME. DECEMBER 8. 1906.
BUREAU STEAM ENGINEERING, NAVY DEPT.
WASHINGTON, D.C. JANUARY 18. 1907.
REVOLUTIONS.
80
85
90
95
100
105
110
115
120
125

## BOILERS.

There are twelve Babcock & Wilcox water-tube boilers of the latest design, arranged two each in six communicating watertight compartments, with athwartship fireroom between each two boilers.

The boilers are identical with those installed in the *Louisiana* and described by Lieutenant R. K. Crank, U. S. N., in Volume XVIII, No. 1, of February, 1906.

## OFFICIAL TRIALS.

### STANDARDIZATION OF SCREWS.

The vessel was tried by the standardized screw method, progressive runs being made over the measured-mile course off Rockland, Maine, December 5, 1906.

From the data obtained on these runs the curves shown on Plate I were plotted.

The draught and corresponding displacement were as follows:

| | Beginning. | End. |
|---|---|---|
| Draught forward, feet and inches, | 24–02 $\frac{7}{16}$ | 24–1 $\frac{5}{8}$ |
| aft, feet and inches, . . | 24–10 $\frac{9}{16}$ | 24–8 $\frac{7}{8}$ |
| Corresponding displacement, tons, | 16,026 | 15,946 |

The results of the runs with and against the tide having been plotted as separate curves, the curve of true speed was obtained, from which it was deduced that a mean of both engines of 114.6 revolutions per minute would be required to give a true speed of 18 knots.

### OFFICIAL FOUR-HOURS' TRIAL.

On the morning of December 7, 1906, the *Vermont* got under way and went to sea for the four-hours' trial. The weather was cold, squally and thick, with snow and rain. There was a moderate breeze from N.N.E. to a moderate gale from W.N.W. Sea moderate to rough.

Draught at beginning of trial, forward, ft. and in., 24–1$\frac{3}{16}$
aft, feet and inches, 25–1$\frac{5}{16}$
Corresponding displacement, tons, . . . . . 16,093
Average revolutions per minute for trial, . . . 117.12
Corresponding speed from curve, knots, . . . 18.33

The following is a synopsis of the data obtained:

*Steam Pressures.* (*Average of one-half hourly observations.*)

| | *Starboard.* | *Port.* |
|---|---|---|
| Mean steam pressure at boilers, pounds | 264.2 | |
| engines, pounds | 259.0 | 258.0 |
| H.P. steam-chest gauge, pounds | 259.0 | 254.0 |
| 1st receiver (absolute), pounds | 99.0 | 105.0 |
| 2d receiver (absolute), pounds | 36.0 | 37.2 |
| Vacuum in condensers, inches of mercury, mean | 26.0 | 26.0 |

*Temperatures.* (*Average of one-half hourly observations.*)

| | *Starboard.* | *Port.* |
|---|---|---|
| Injection, degrees | 45.0 | 45.0 |
| Discharge, degrees | 117.0 | 109.0 |
| Hotwell, degrees | 87.0 | 82.0 |
| Feed water, degrees | 177.0 | 158.0 |
| Engine room, working platform, degrees | 58.0 | 58.0 |
| Firerooms, working level, degrees | 50.9 | 50.9 |
| Smoke stacks, average, degrees | 450.0 | |

*Revolutions, or double strokes, per minute.* (*Average of one-half hourly observations.*)

| | | |
|---|---|---|
| Average revolutions, main engines, per minute | 117.16 | 117.05 |
| Mean revolutions, both engines, per minute | 117.10 | |
| Pumps, main air | 14.3 | 13.0 |
| circulating | 176.0 | 193.0 |
| feed, d.s., per minute | 22.0 | 24.0 |
| fire and bilge | 44.0 | 45.0 |
| Dynamos | 118.0 | |
| Blower engines | 138.0 | |
| Speed of ship, in knots per hour | 18.33 | |
| Slip of propeller, in per cent. of its own speed, based on mean pitch | 12.38 | 12.09 |
| Air pressure in firerooms, in inches of water, mean | 1.47 | |

*Mean Effective Pressures in Cylinders, in pounds per square inch.* (*Averages of cards taken at half-hourly periods.*)

| | | |
|---|---|---|
| Main engines, H.P. cylinder | 120.0 | 110.0 |
| I.P. cylinder | 45.6 | 48.6 |
| F.L.P. cylinder | 19.9 | 21.3 |
| A.L.P. cylinder | 19.8 | 21.3 |

| | *Starboard.* | *Port.* |
|---|---|---|
| Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons | 53.7 | 54.39 |

INDICATED HORSEPOWER.

| | | |
|---|---|---|
| Main engines, H.P. cylinder | 2,757.0 | 2,528.0 |
| I.P. cylinder | 2,833.0 | 3,016.0 |
| F.L.P. cylinder | 1,641.0 | 1,660.0 |
| A.L.P. cylinder | 1,633.0 | 1,756.0 |
| total | 8,864.0 | 8,960.0 |
| Collective H.P. of both main engines | | **17,624.0** |
| Air pumps, main<br>Circulating pumps, main<br>Feed pumps, main<br>Hotwell pumps | | 358.0 |
| Other auxiliaries | | 267.0 |
| Total | | 18,249.0 |

COAL.

| | |
|---|---|
| Pounds, per hour, main and auxiliary engines, during trial | 36,450.0 |

DEDUCED DATA.

| | |
|---|---|
| I.H.P. (total) per square foot of grate surface | 16.59 |
| main engines, air, circulating and feed pumps, per square foot of grate surface | 16.35 |
| main engines, air, circulating and feed pumps, per square foot of heating surface | 0.34 |
| Pounds of coal per I.H.P. per hour, collective, main engines, air, circulating and feed pumps | 2.03 |
| Pounds of coal per I.H.P. per hour, all machinery in operation | 1.942 |
| square foot of grate surface, per hour | 32.23 |
| Cooling surface (main condenser), square feet per I.H.P. (main engine) | 1.177 |
| Heating surface, square feet per I.H.P. (total) | 2.89 |

OFFICIAL TWENTY-FOUR-HOURS' TRIAL.

Immediately after the four-hours' trial the twenty-four-hours' endurance trial required by the contract commenced. The weather was very cold, thick and squally, with moderate to stiff gale from N.N.W. to W.N.W. Rough sea. The average indicated horsepower of the main engines on this trial was 14,935. Average revolutions, 110.34; corresponding speed from curve, 17.43. The following is a synopsis of the data obtained:

*Steam Pressures.* (*Average of one-half hourly observations.*)

| | Starboard. | Port. |
|---|---|---|
| Mean steam pressure at boilers, pounds | 236.2 | |
| engines, pounds | 234.7 | 234.9 |
| H.P. steam chest gauge, pounds | 222.2 | 219.8 |
| 1st receiver (absolute), pounds | 82.6 | 92.0 |
| 2d receiver (absolute), pounds | 29.9 | 32.0 |
| Vacuum in condensers, inches of mercury, mean | 25.9 | 26.5 |

*Temperatures.* (*Average of one-half hourly observations.*)

| | | |
|---|---|---|
| Injection, degrees | 45.9 | 46.0 |
| Discharge, degrees | 111.2 | 116.5 |
| Hotwell, degrees | 82.0 | 86.4 |
| Feed water, degrees | 165.1 | 153.8 |
| Engine room, working platform, degrees | 64.2 | 63.3 |
| Firerooms, working level, degrees | 47.5 | 47.5 |
| Smoke stacks, average, degrees | 450.0 | |

*Revolutions, or double strokes, per minute.* (*Average of one-half hourly observations.*)

| | | |
|---|---|---|
| Average revolutions, main engines, per minute | 110.4 | 110.2 |
| Mean revolutions, both engines, per minute | 110.3 | |
| Pumps, main air | 14.4 | 13.8 |
| circulating | 176.3 | 162.3 |
| feed, d.s., per minute | 19.7 | 22.4 |
| fire and bilge | 44.2 | 26.4 |
| Blower engines | 294.5 | |
| Speed of ship, in knots per hour | 17.43 | |
| Slip of propeller, in per cent. of its own speed, based on mean pitch | 11.21 | 11.26 |
| Air pressure in firerooms, in inches of water, mean | 1.04 | |

*Mean Effective Pressures in Cylinders, in pounds per square inch.* (*Averages of cards taken at half-hourly periods.*)

| | | |
|---|---|---|
| Main engines, H.P. cylinder | 112.4 | 99.6 |
| I.P. cylinder | 39.2 | 42.7 |
| F.L.P. cylinder | 17.5 | 18.4 |
| A.L.P. cylinder | 16.9 | 18.4 |
| Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons | 47.73 | 48.37 |

INDICATED HORSEPOWER.

| | | |
|---|---|---|
| Main engines, H.P. cylinder | 2,440.0 | 2,152.0 |
| I.P. cylinder | 2,311.0 | 2,492.0 |
| F.L.P. cylinder | 1,363.0 | 1,427.0 |
| A.L.P. cylinder | 1,319.0 | 1,431.0 |
| total | 7,433.0 | 7,502.0 |

| | *Starboard.* | *Port.* |
|---|---|---|
| Collective H.P. of both main engines | **14,985.0** | |
| Air pumps, main | | |
| Circulating pumps, main | | |
| Feed pumps, main | 292.0 | |
| Hotwell pumps | | |
| Other auxiliaries | 185.0 | |
| Total, all machinery | 15,412.0 | |

DEDUCED DATA.

| | |
|---|---|
| I.H.P. (total) per square foot of grate surface | 14.01 |
| Cooling surface (main condenser), square feet per I.H.P. (main engine) | 1.347 |
| Heating surface, square feet per I.H.P. (total) | 3.422 |

# THE ADVANTAGES OF A SYSTEMATIC AND REGULAR METHOD OF WORKING THE FIRES IN A BOILER.

By Lieutenant Commander R. K. Crank, U. S. N., Member.

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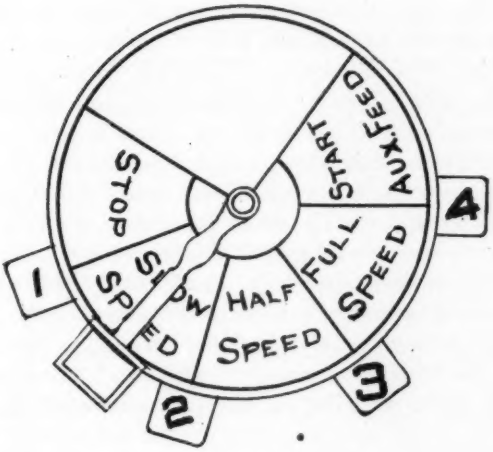
It is thought that the advantages of some regular systematic method of working the fires aboard ship over the old unmethodical way of "every man for himself" are so apparent to anyone, be he officer or enlisted man, who has had any experience with and without any systematic method, that it is unnecessary to dilate unduly upon these advantages. The average sailor-man will growl over the introduction of any innovation, for the reason that it is new and because he likes to growl; but, if one may judge from the experience on this ship (*Louisiana*), not a single fireman would vote to go back to the old way of working the fires.

The advantages of a regular, systematic method of working fires, by periodic signals to the firerooms, were deeply impressed on the writer on the trial trips of a number of the new and larger ships which he attended in the winter of 1905-1906, especially when the well-ordered methods in the firerooms of the *Louisiana* on her trial were contrasted with the comparatively confused conditions in the firerooms of the *Missouri* on the trial of that vessel by the same builders. These two examples alone were sufficiently convincing.

Assuming the advantages of a system to be indisputable, the writer submits these notes in the hope that they may contain some suggestion that may prove of use to officers on board those ships in which no automatic signals for working fires have been fitted or used and in which no regular system of firing has been employed.




U. S. S. "LOUISIANA."

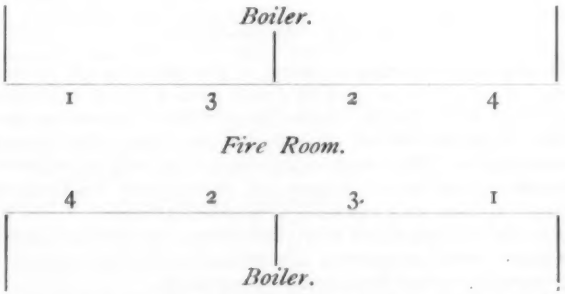
**Sketch showing the method of fitting a fireroom telegraph for use as a transmitter of signals for working the fires in rotation and at fixed intervals. The figures by which the furnaces are designated are painted on pieces of sheet brass which are fastened opposite the lines between the divisions on the face of the dial. The pointer of the dial is fitted with an extension, cut so as to form a frame for each number and painted so as to indicate beyond possibility of mistake what number it is intended to signal.**

**To make any ordinary signal other than a signal for working a particular fire, the pointer would be placed in the middle of a division, as shown in the sketch, where the signal "Slow Speed" is indicated.**

In August, 1906, about one month after the *Louisiana* quitted the Norfolk Navy Yard on her first service after commissioning, the fireroom telegraphs were fitted so as to permit them to be used as transmitters for sending firing signals. The accompanying sketch shows the manner in which each transmitter was fitted. As will be seen, the numbers by which the different furnaces or fires are designated were marked in large figures on pieces of sheet brass which were secured to the back of the dial and opposite the lines of demarcation between the divisions already on the face of the dial (that is, the divisions marked "Stop," "Slow Speed," "Half Speed," etc.). When it is desired to send a signal such as "Stop," "Slow

Speed," etc., the pointer of the telegraph is put in the middle of the proper division on the face of the dial (in the sketch, "Slow Speed" is indicated). When the telegraph is in use for transmitting signals for working the fires the pointer is placed opposite and in line with one of the figures by which a particular fire is designated. A man is stationed at the telegraph in the starboard engine room, with a time-piece, and instructed to send the signals in rotation at a stated interval between two successive signals. After trial it was found that, for ordinary cruising speed (12 to 13 knots), with about seven-twelfths boiler power, the interval between successive signals should be about two minutes. This interval, for any particular ship, can be determined only by trial.

Facing the boiler, the furnaces are numbered as shown below, viz:




This numbering of the furnaces is slightly different from the numbering at the time of the trial for reasons that will be given later.

The cycle and sequence of operations followed in working the fires are as follows, viz: Whenever a signal was received in the fireroom, the fire indicated by that signal (No. 1, 2, 3 or 4) was *raked,* and, immediately afterwards and without any further signal, the fire next to the one just raked and on the same side of the boiler with the one just raked, was coaled. Always, on receiving a signal, the first operation was to *rake* the fire indicated by the signal and then coal the one next to it. The sequence, therefore, would be:

| Signal. | 1st operation. | 2d operation. |
|---|---|---|
| No. 1 | Rake Fire No. 1 | Coal Fire No. 3. |
| No. 2 | Rake Fire No. 2 | Coal Fire No. 4. |
| No. 3 | Rake Fire No. 3 | Coal Fire No. 1. |
| No. 4 | Rake Fire No. 4 | Coal Fire No. 2. |

Taking any one fire (as No. 1), it will be seen that it is raked in one cycle and coaled in the next; also, referring to the diagram of the numbering of the furnaces, it will be seen that there is always a bright fire and a freshly-coaled fire in the same side of the boiler. With the numbering of the furnaces on the trial, there would be always two bright fires together in one half of the boiler and two green fires together in the other half of the boiler.

In order to counteract the persistent tendency of the firemen to fire too heavily and to pile the coal up in the front of the furnace, particularly in the cases of those men who had been accustomed to firing Scotch boilers by firing "on the dead plate" where the fresh charge was allowed to coke before being shoved back, orders were given that not more than four shovelfuls of coal should be put on any one fire at one time. With a regular system of firing it was possible to go into any fireroom at any time at sea, and, by an inspection of any fire, to determine whether or not the fireman had been carrying out orders and whether or not he was firing properly and efficiently. Although great improvement resulted from the use of the system and the limiting the amount to be put on any one fire, it has not been possible, in the five months of steaming since commissioning, to get the older firemen into the habit of carrying level, light fires, despite entreaties, prayers, profanity and dire threats. With a good system of firing signals it would be possible to make better firemen, for a particular type of boiler, from green men who had never fired at all, but who were intelligent and willing to do as they were told, than from old men who consider themselves past masters in the art of firing. An efficient feed-water regulator would prove of the greatest assistance, for the average water-tender is so constantly exercised and preoccupied, with a water-tube boiler, in watching the water level in the gauge glass and

tending the throttle of the feed pump or manipulating the check valve that he devotes little or no attention to the working of the fires. With a systematic method of firing and a feed regulator that would maintain a constant water level there would result a regularity of steam pressure and an evenness of distribution of the work amongst the boilers in use that would conduce greatly to economy of steam production, to the maintenance of a regular speed, to the life of the boilers and to the peace of mind and comfort of the entire engineering personnel. We hear of special courses of instruction for every special class of men in the service except those who have to do with the motive power. When the conditions of the service will permit, special instruction on special ships should be given in firing and the rudiments of engine driving and the care of as to firing guns the results would be little short of amazing; machinery. If as much thought were given to firing boilers but, lacking these Utopian conditions, much may be accomplished by sea-going officers with the material on board. The adoption of any sort of a system of firing, by the increased regularity and economy in the production of steam and the gauge it affords on the abilities of the men, will amply repay the slight effort needed to put it in operation.

# A NEW FORM OF AUTOMATIC ASSISTANT CYLINDER FOR VALVE GEARS.

By Luther D. Lovekin, Associate.

The subject of assistant cylinders for relieving the forces of inertia and gravity in connection with reciprocating valve gears is one which the writer has given years of attention, and at this writing 115 of these cylinders are in practical use in various naval and merchant vessels throughout the world.

Several forms have been used in order to obtain the best results in each particular case, and, like all other devices which require a thorough scientific investigation being made in order to fully understand the principle upon which it is based, this cylinder has been no exception to the rule of conservatism so prevalent among designing engineers. This is not surprising, when we consider the number of various devices that are brought before the engineer daily for his consideration, and with only a limited amount of time at his disposal for reviewing the same.

Being fully cognizant of these conditions, I have contributed from time to time various articles dealing with this subject, so as to bring the entire matter before the engineering world gradually.

I believe the time has now arrived when I can safely state that all required conditions have been fully met by some particular form of assistant cylinder among my various designs.

Within the past six months, however, I have brought out a cylinder which embodies the chief characteristics sought for by the designer, viz: simplicity, economy, automatic regulation, ease of application, and an assurance of the theoretical requirements being fulfilled in practice as closely as possible.

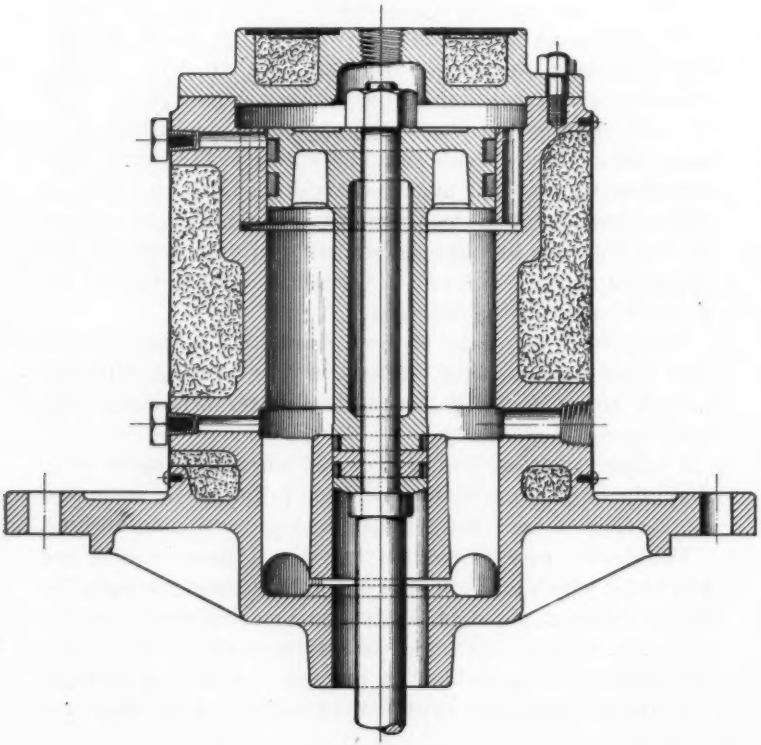
I take great pleasure in presenting herewith a full and com-

plete description of my automatic assistant cylinders, which I hope will be of interest to all concerned.

If a further investigation is required, I would refer to the different articles which have appeared at various times, and which I believe form an exhaustive treatise on this subject, viz: "Assistant Cylinders," published in the JOURNAL AMERICAN SOCIETY OF NAVAL ENGINEERS," Volume XVI, Nos. 1 and 3; and Volume XVII, No. 3. Also "Proceedings of the Society of Naval Architects and Marine Engineers," November, 1902 (prize essay).

THE LOVEKIN IMPROVED ASSISTANT CYLINDER

TYPE "A"



## THE LOVEKIN IMPROVED "ASSISTANT CYLINDER" FOR VALVE GEARS.

*Type A.*—This type comprises a valve-chest bonnet and "assistant cylinder" combined in one piece, and is used in connection with an engine having piston valves, which necessarily requires a circular valve-chest bonnet or cover over the same.

It will be noticed that the "assistant cylinder" receives its supply of steam from its own valve chest or receiver, and consequently requires no piping or valves whatever. It is entirely automatic in its action, and has the least number of parts possible to secure the desired results. It is designed in such a manner that the circular steam-inlet port at the lower end serves the purpose of admitting steam from its own receiver, and also forms an automatic drain for releasing any water that might collect in the lower part of the cylinder. The upper end of the "assistant cylinder" is designed to secure the best results in each individual case; the particulars of same are determined by the theoretical diagram (which decides whether no compression top is required, or otherwise). It is drained automatically, through the ports shown, into the lower part of the "assistant cylinder," and thence to the steam chest below.

NOTE.—Both upper and lower ends of cylinder are automatically drained during every revolution of the engine.

*Piston.*—The piston, as will be seen, is of the differential type; the diameter of the lower end being determined by the velocity of steam necessary at the inlet port. Both of these pistons have packing rings of the usual form, and of such width as is found necessary for riding over the narrow slotted ports in upper and lower cylinders, as shown.

The conditions of admission and compression are designed for each individual case in order to balance the forces due to inertia and gravity.

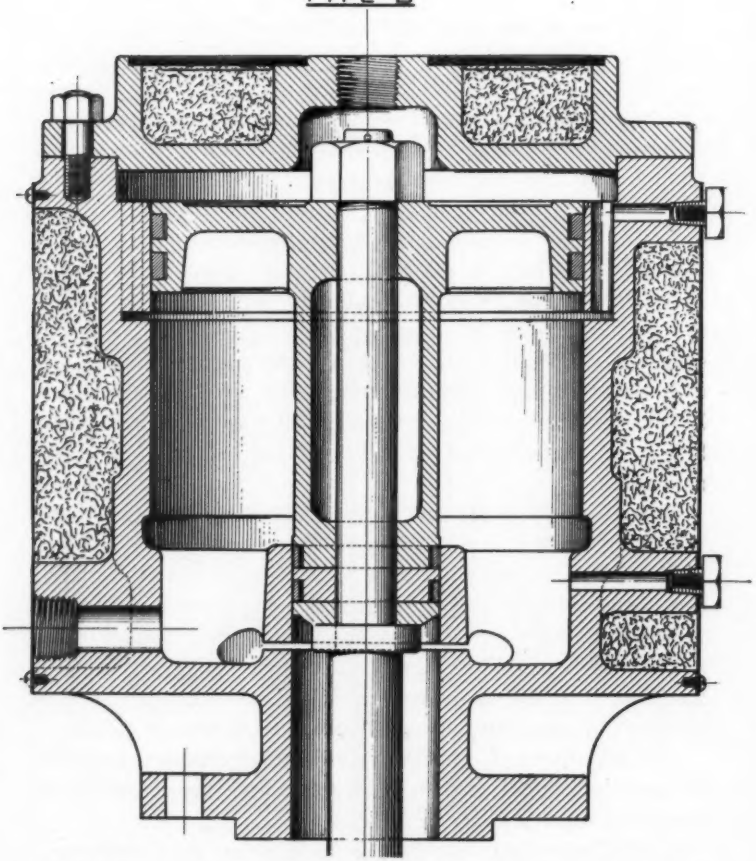
It will be noticed that there is *no exhaust port whatever;* consequently the only steam used in connection with a cylin-

der of this type is the amount necessary to make up the losses due to radiation and condensation.

The principal feature of this design is the ability to form a movable steam-tight packing in the lower cylinder and thus

THE LOVEKIN IMPROVED ASSISTANT CYLINDER

TYPE "B"



allow compression to be maintained in the upper cylinder. This is accomplished by means of packing rings in the piston,

as shown ; and necessitates *the lower cylinder bore being of a length equal, at least, to the travel of the main valve.*

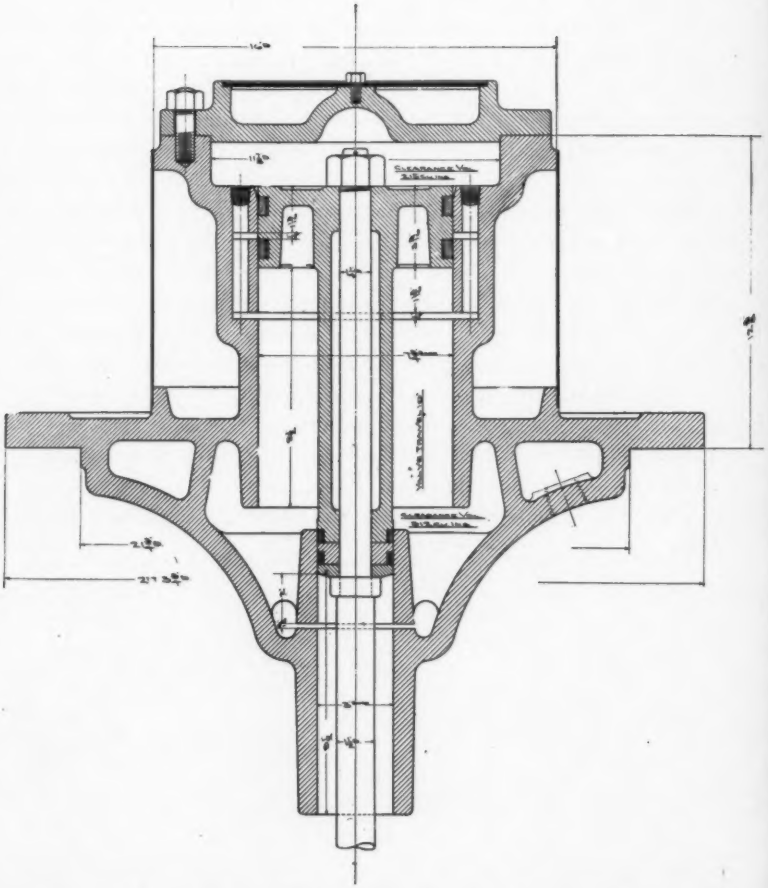
NOTE.—The description of assistant cylinder as given for Type A also serves for illustrating the action of Types B and E, as each of these as shown are fully automatic and require no pipes, no valves to manipulate, and have no complication of parts. They can also be fitted to any engine, old or new.

*Type B.*—Type B cylinder has the same characteristics as Type A.

This cylinder is designed for use in connection with flat slide valves, and is either bolted directly to the steam-chest cover, or secured to the top of steam chest in the event of steam-chest covers being arranged at the end of the cylinder.

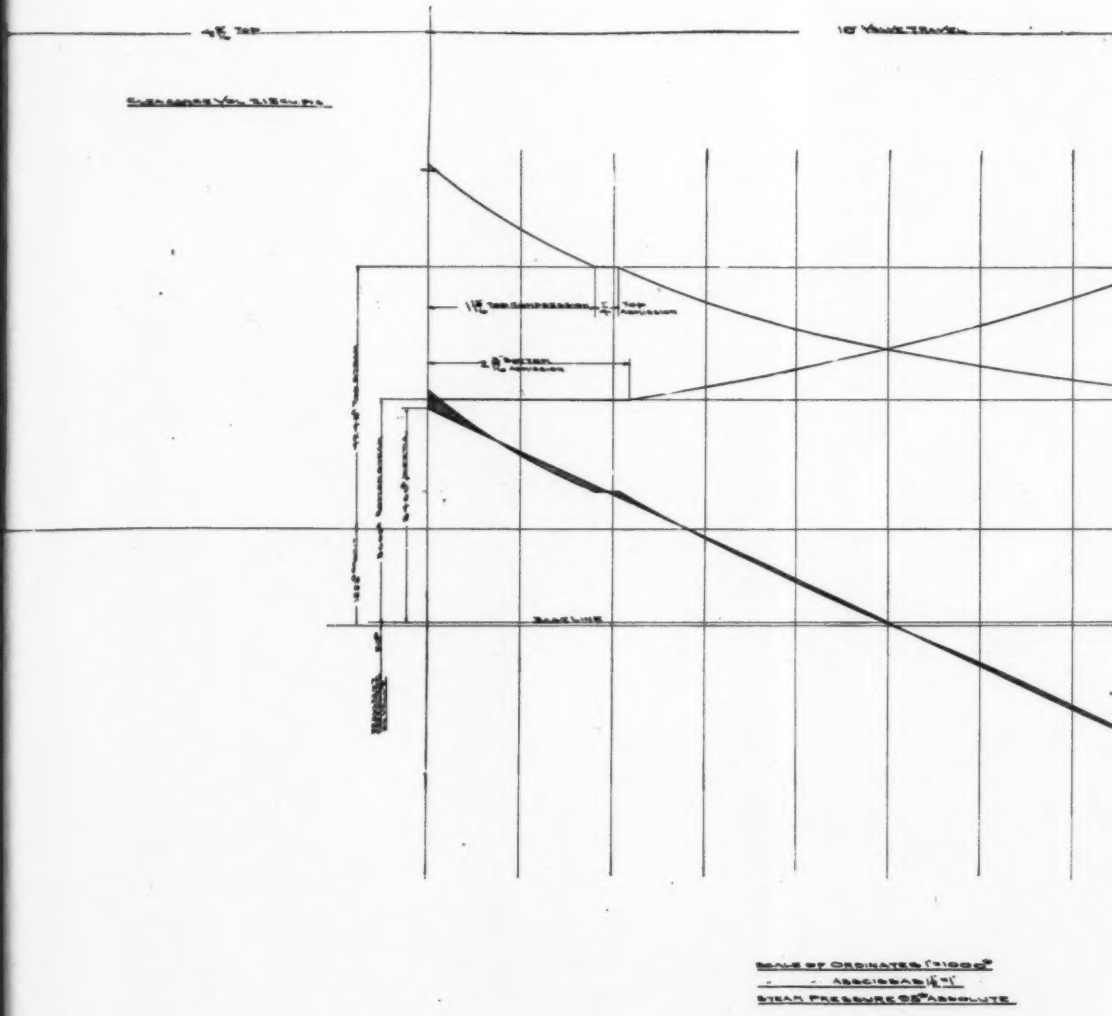
*Type E.*—This type is used in connection with high-speed engines, where the inertia top plays an important part. It can be designed to fulfil the same requirements as Type D. Each cylinder, however, is dependent upon its own receiver pressure, and consequently when fitted on the L.P. valve gears they will be of larger diameter than Type D.

The chief characteristics are the same as described for Type A.



PRELIMINARY DESIGN OF TYPE E, FOR THE VALVE GEAR OF THE INTERMEDIATE CYLINDER, U. S. BATTLESHIP "MICHIGAN."

XU



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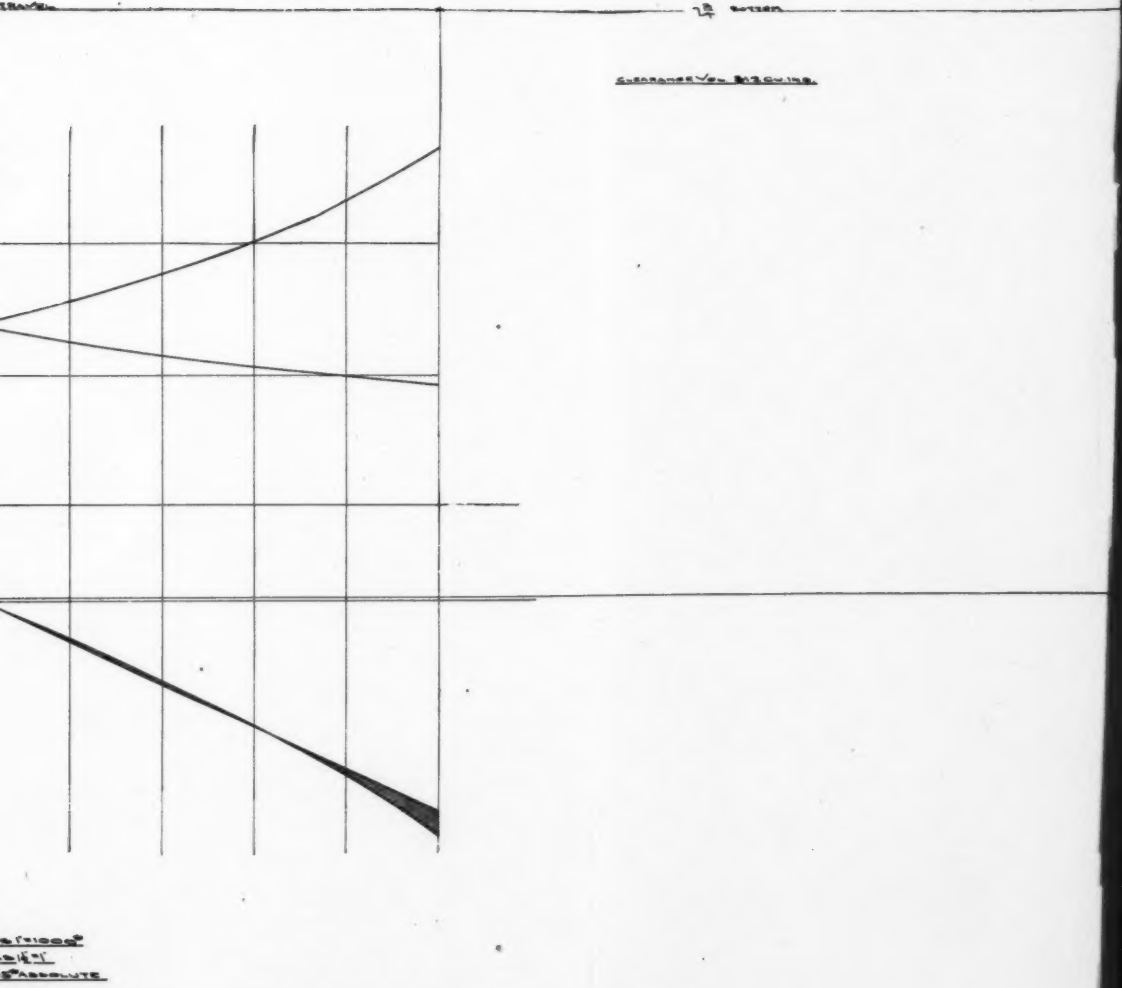
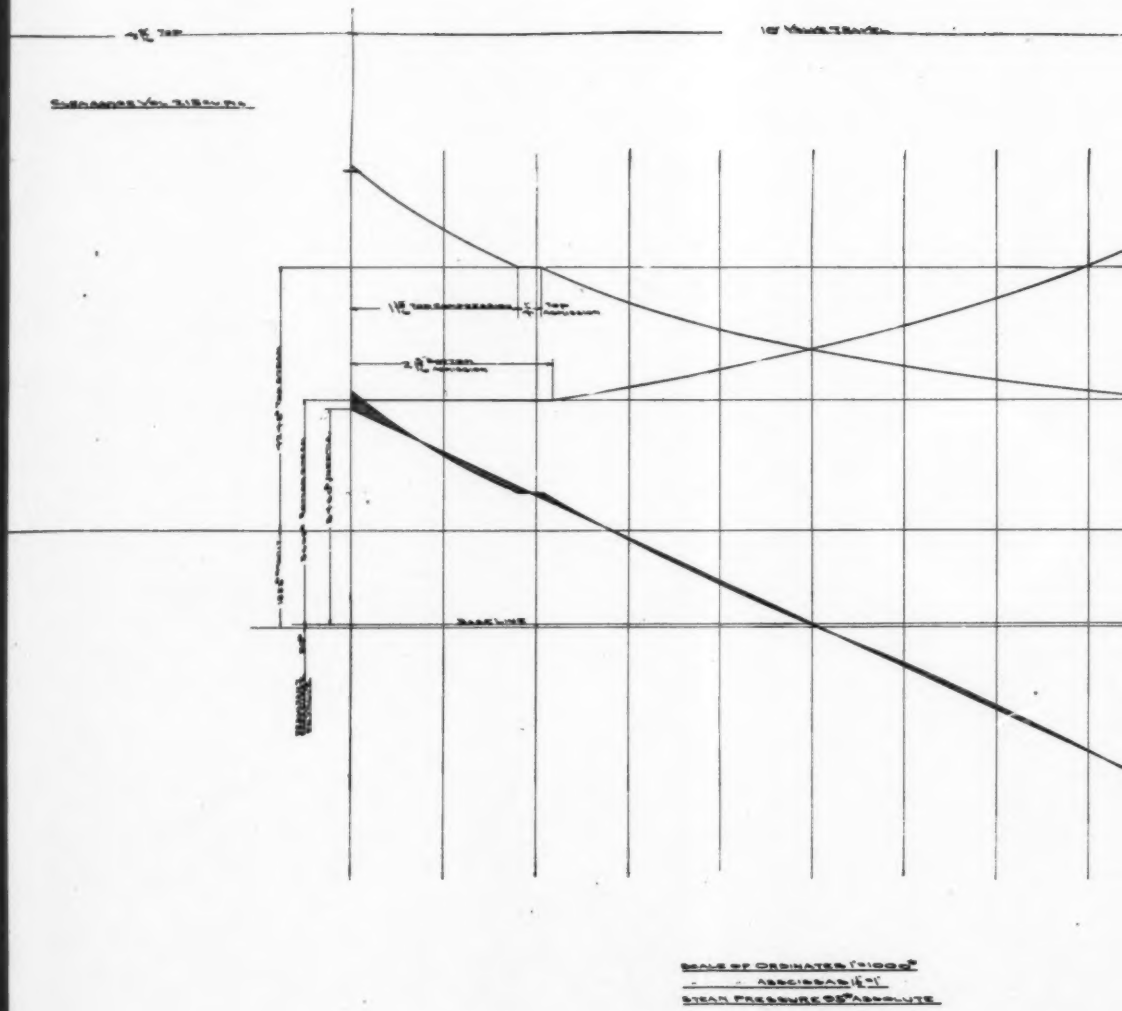


FOR THE VALVE GEAR OF THE INTERMEDIATE CYLINDER, U. S. BATTLESHIP "MICHIGAN."



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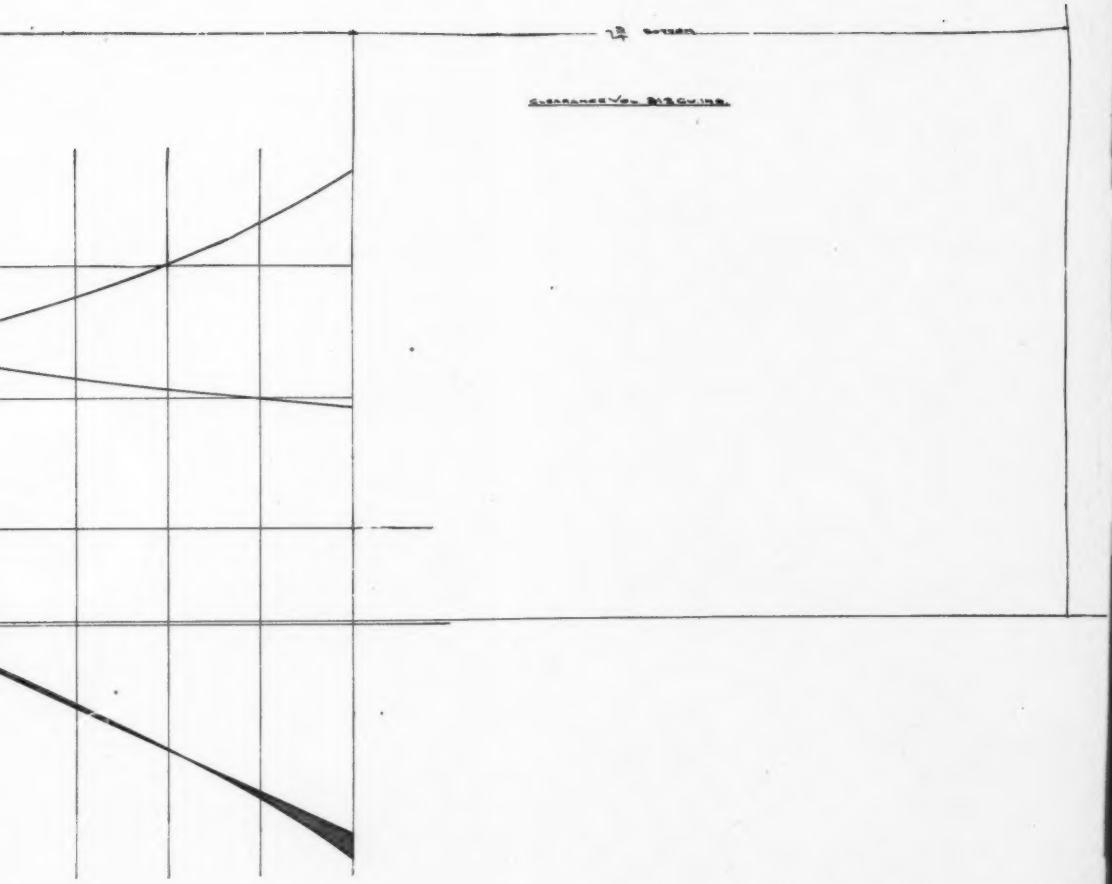
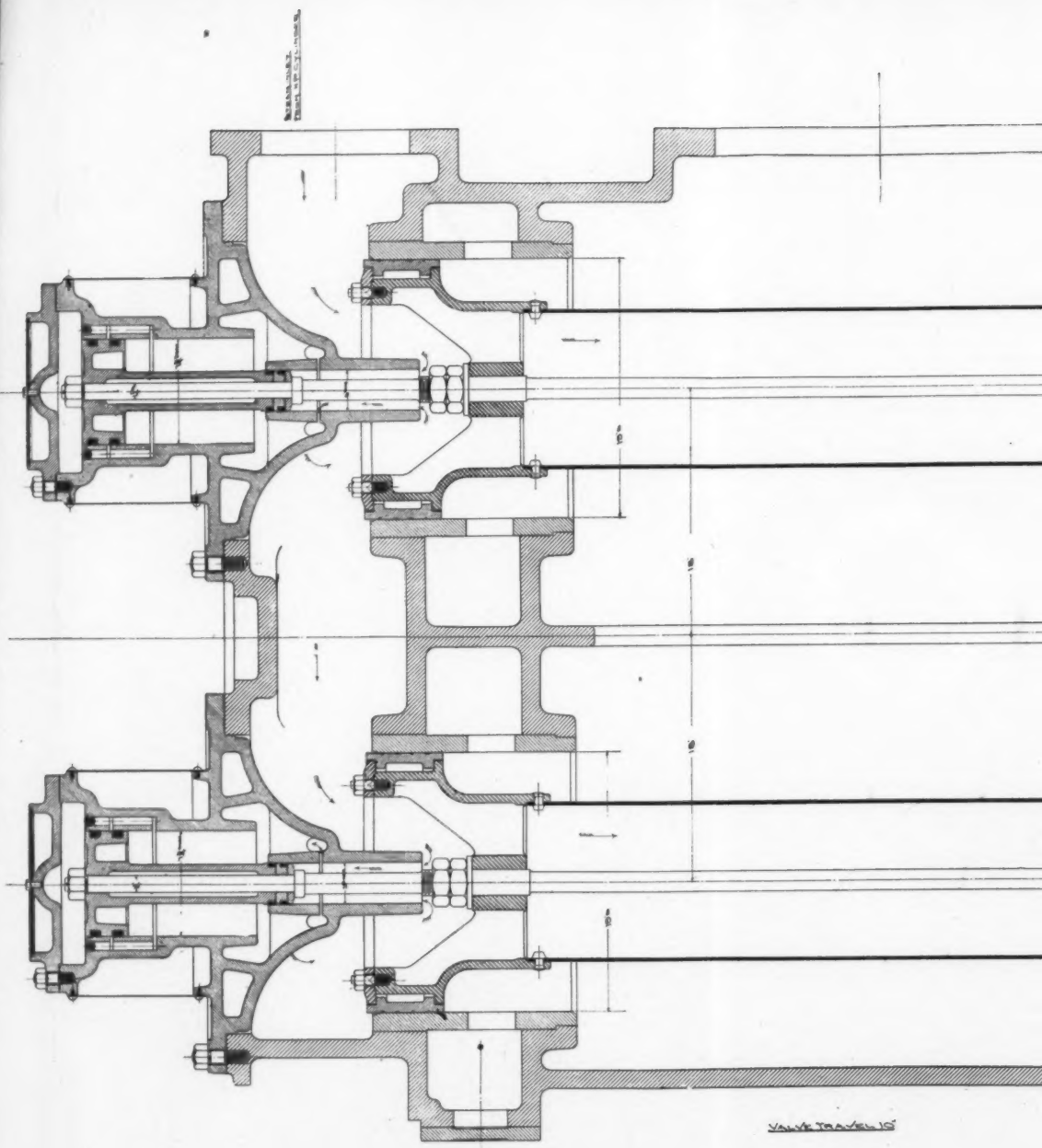
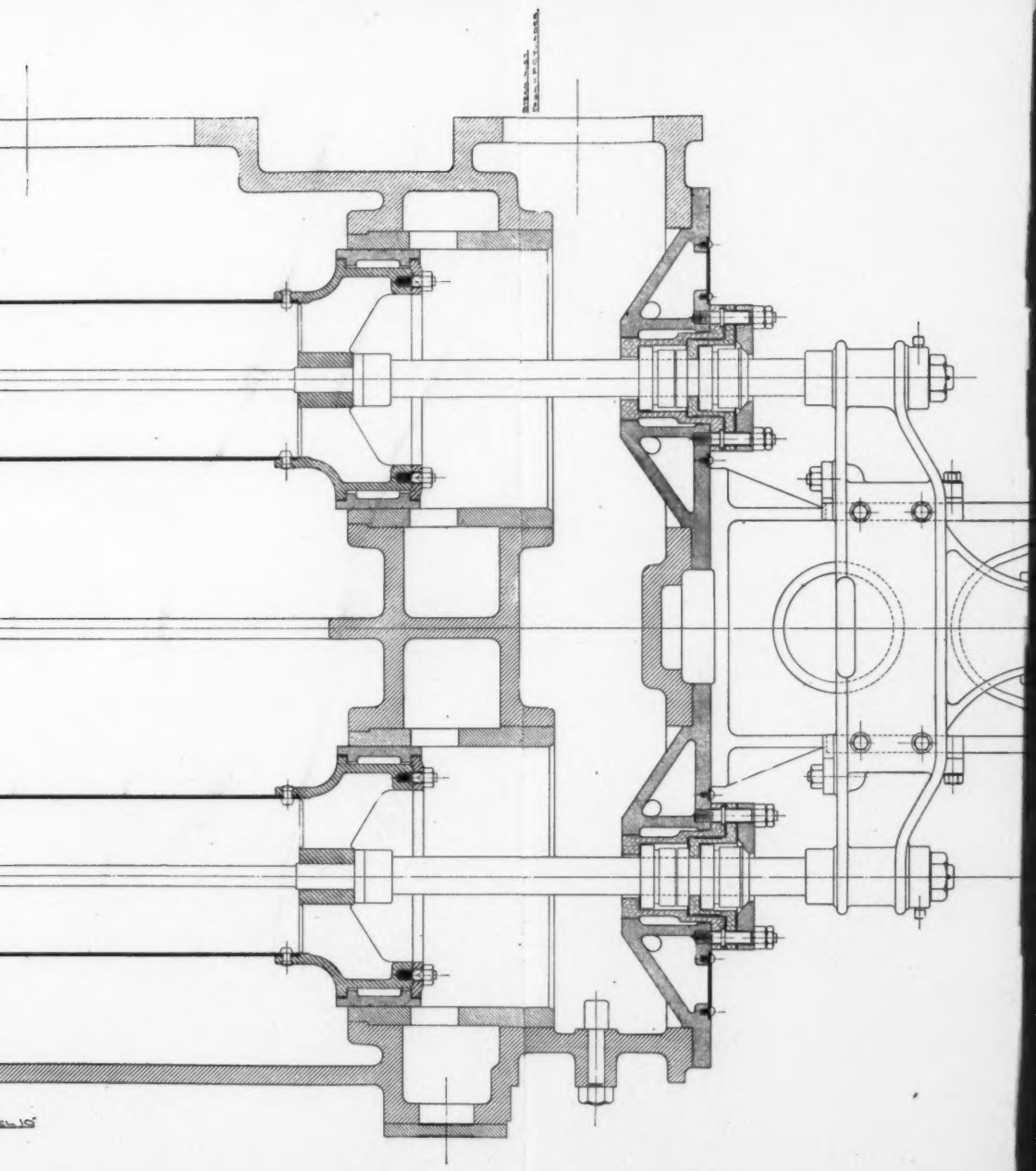


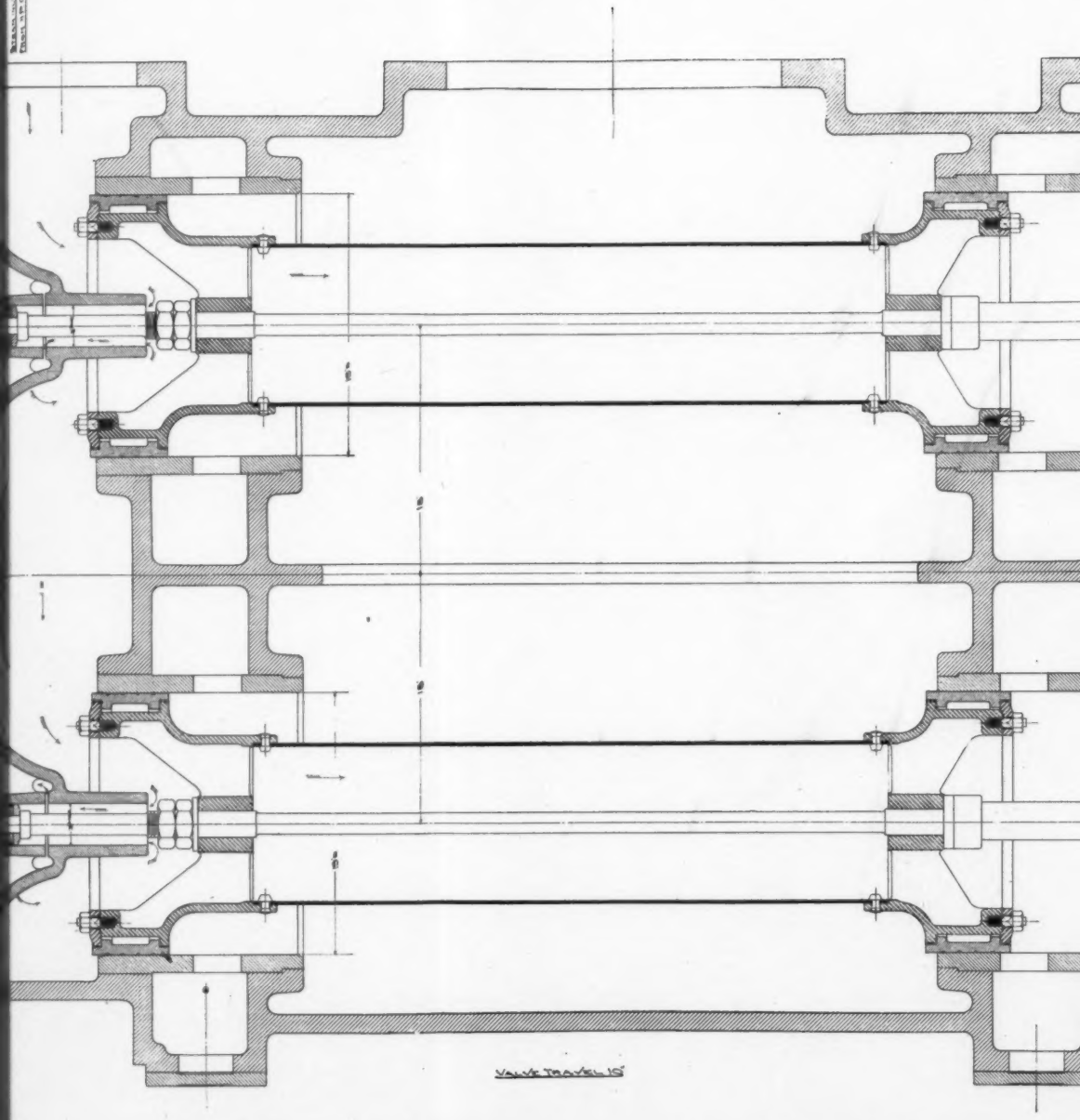
Valve Gear of the Intermediate Cylinder, U. S. Battleship "Michigan."



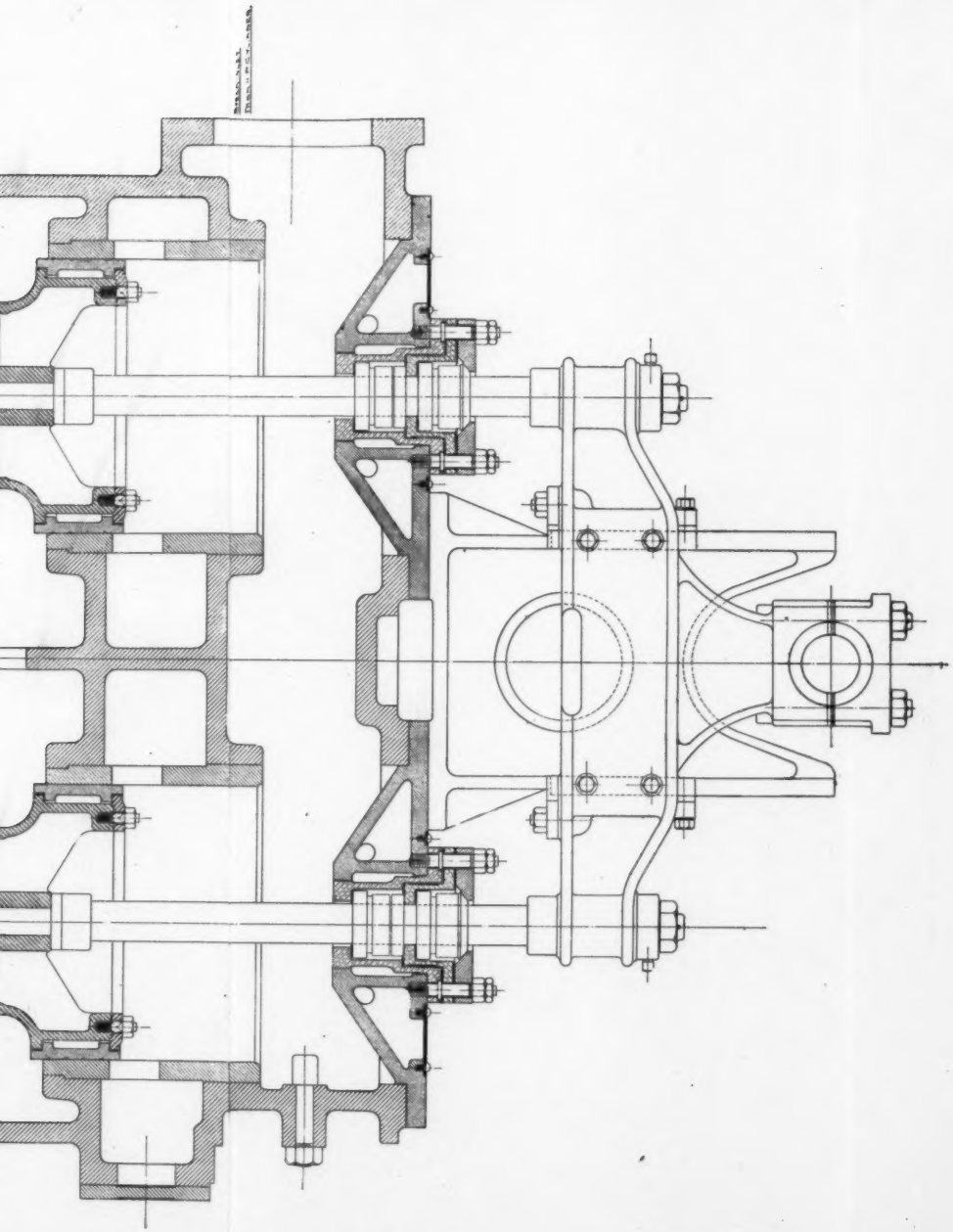

DESIGN SHOWING TYPE E, AS APPLIED TO THE VALVE GEAR OF TH



VALVE GEAR OF THE INTERMEDIATE CYLINDER, U. S. BATTLESHIP "MICHIGAN."



DESIGN SHOWING TYPE E, AS APPLIED TO THE VALVE GEAR OF THE INTERMEDIATE CYLINDER, U. S.



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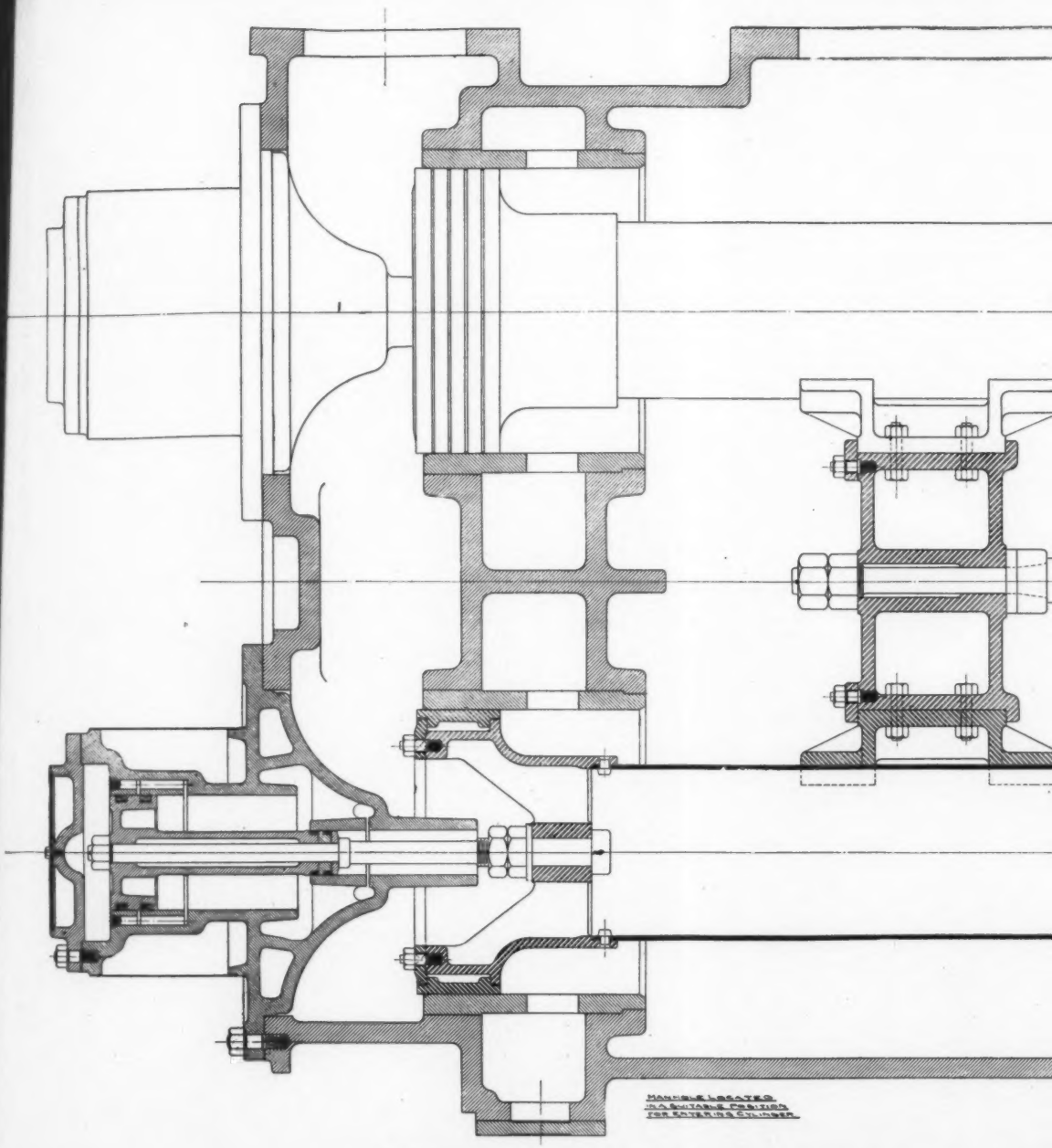
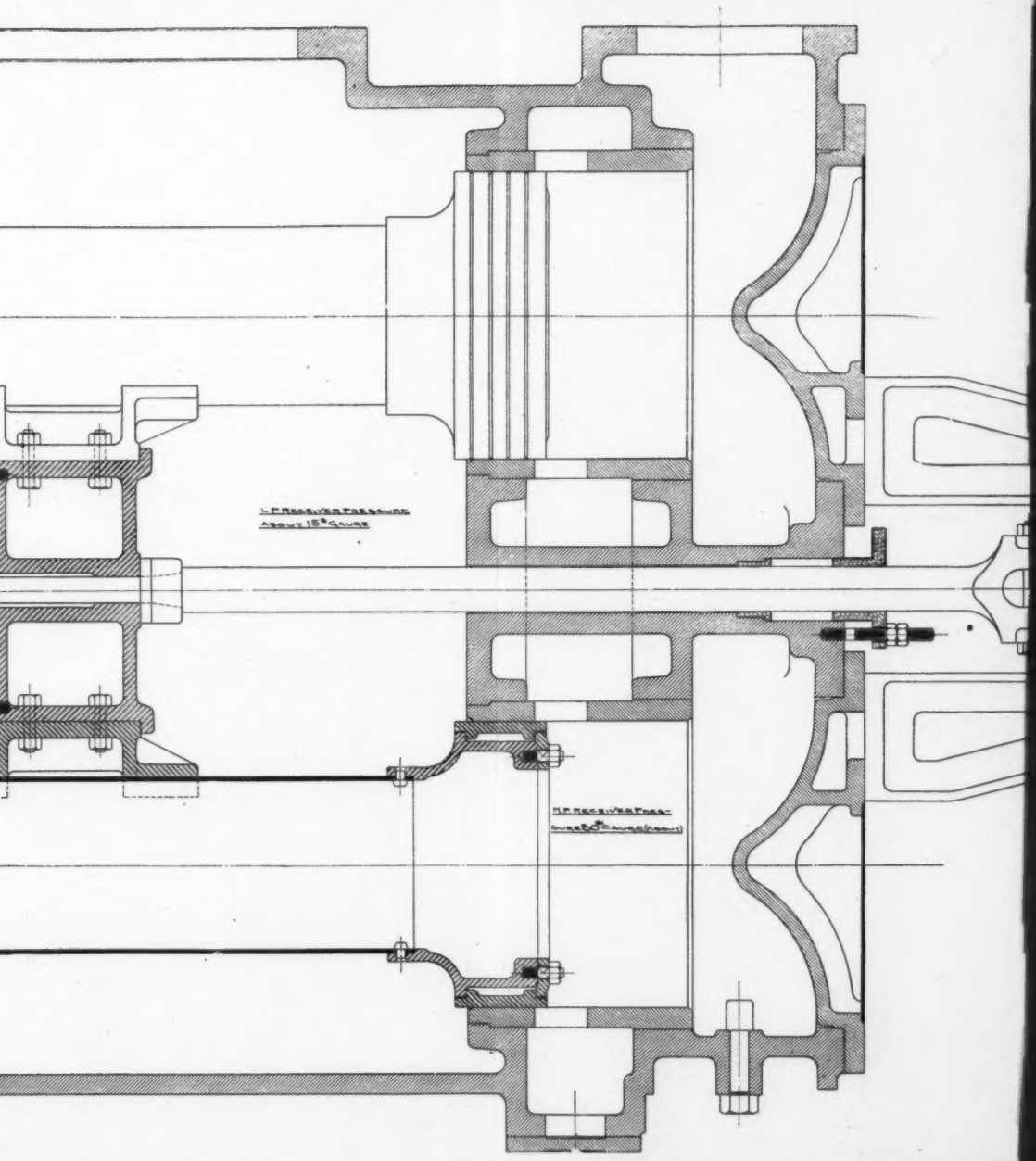
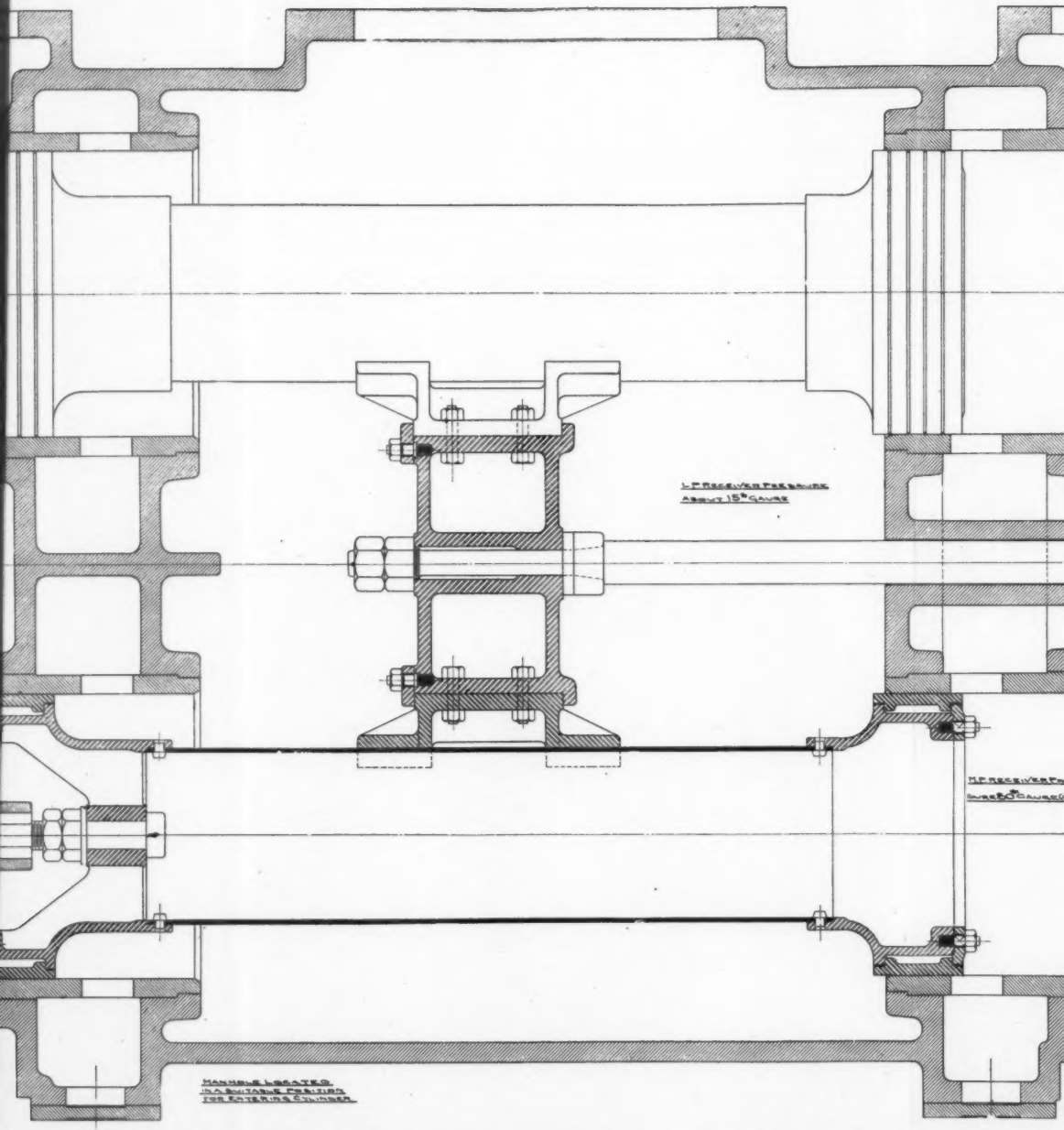


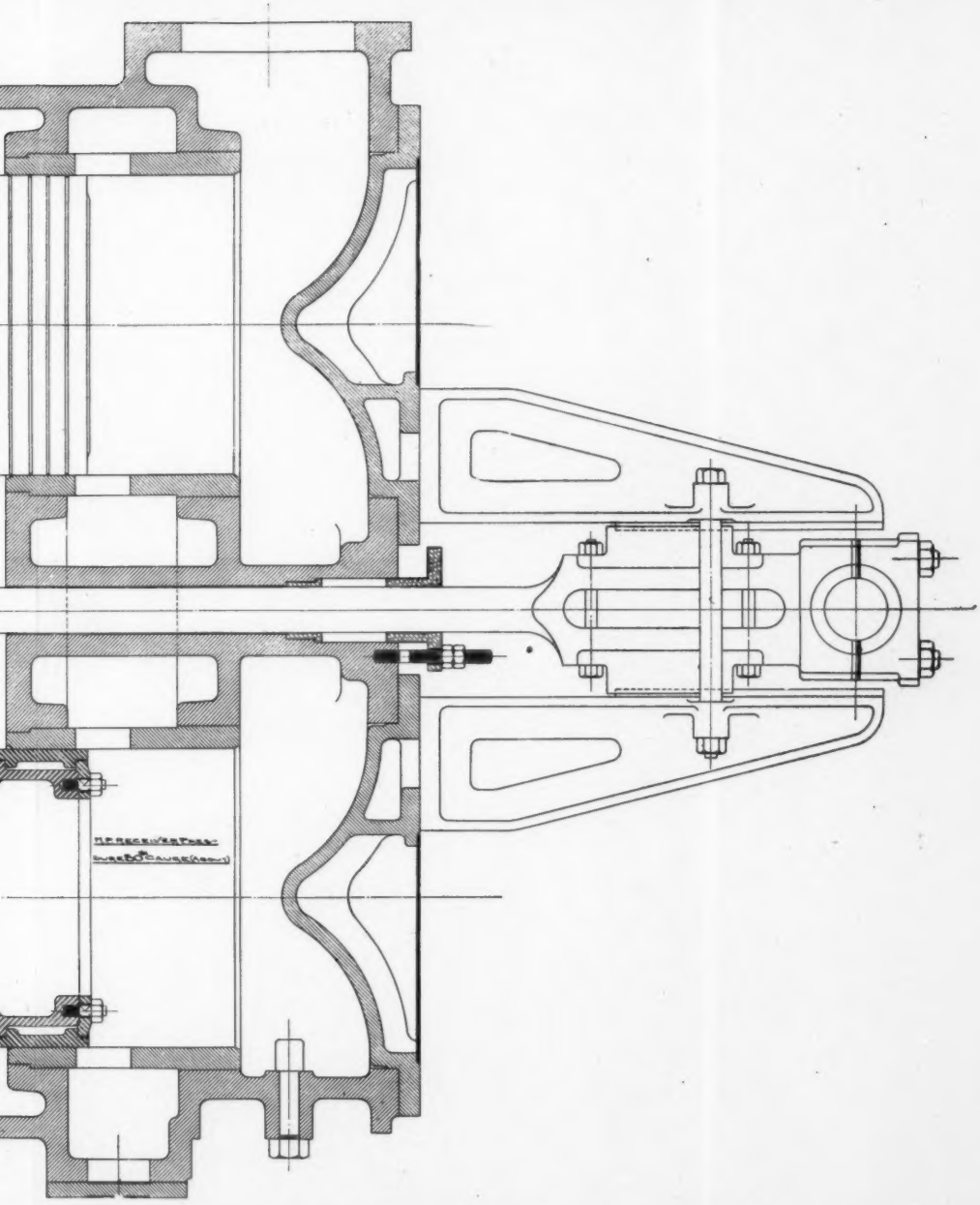

ALTERNATIVE DESIGN SHOWING TYPE E, WITH INTERNAL CROSSHEAD, AS APPLI




Crosshead, as Applied to the Valve Gear of the Intermediate Cylinder, U. S. Battleship "Michigan."




TIVE DESIGN SHOWING TYPE E, WITH INTERNAL CROSSHEAD, AS APPLIED TO THE VALVE GEAR OF THE INTERMEDIATE CYL



IE INTERMEDIATE CYLINDER, U. S. BATTLESHIP "MICHIGAN."

# NOTES.

## SOME CHARACTERISTICS OF COAL AS AFFECTING PERFORMANCE OF STEAM BOILERS.

By W. L. Abbott.

For the purpose of determining, if possible, some simple rules by which the value of coal screenings could be determined without a continuous boiler test going on in a power house, the Chicago Edison Company proposed a series of tests. Mr. Bement was placed in charge of these, and the results and conclusions given are drawn from his reports.

In general these tests were made to determine the effect of varying percentages of ash and of different grades of fineness upon the value of the coal. To determine the effect of fineness or size, a large sample of coal, amounting to 100 tons or more, was taken and screened through sieves of different mesh until we got several piles of coal, each of approximately uniform size, and with each of these samples boiler tests were made. The results of these are shown in the diagram (Fig. 2), the upper curve indicating the horsepower obtained, or the *capacity*, and the lower curve the *efficiency* derived from these various sizes. It will be observed that the grade of coal nearest in size to a mesh ¾ inch square gave the highest capacity and at the same time the greatest efficiency. The reason for the variation in the values of the different sizes is partially explained by the fact that the smaller sizes carry a greater amount of ash, but it is not ash alone which accounts for all of the difference.

To further investigate the effect of size upon capacity and efficiency a series of 62 tests on ordinary screenings were analyzed, and the efficiencies and capacities which were obtained from these tests are plotted in diagrams (Figs. 4 and

5). A curious and unexpected result is shown. As might have been expected, screenings having an average size of 0.1 inch or under gave the lowest results. As the average

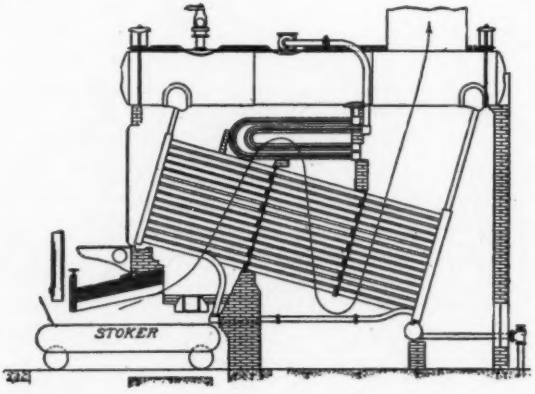



**Fig. 1.**—Elevation of Boiler and Stoker Employed in the Experiments.

size of the coal increased up to about 0.3 inch, the efficiency and the horsepower increased with it. From that point, as the coal became coarser, the efficiency dropped off until reaching a size something less than ½ inch, from which point it again increased.

Referring to Fig. 2, coal through a ¼ inch square screen produced only 108 horsepower, yet a size of fuel known in Illinois as No. 5 washed coal, which will pass through a ¼ inch round hole (a smaller aperture than the square opening) will produce as high as 600 horsepower under the same boiler.

It is probably true that if coal which contains so much dust that we would be unable to get one-half boiler capacity out of it, were put through a washer and freed from this objectionable fine dust only, not more than 3 per cent. of the combustible would be lost in the process. This would indicate that if the coal operator could free his coal from this 3 per cent. of dust, either by washing or, perhaps easier, by fanning,

he could vastly improve the quality of his coal at a very slight loss of 3 per cent. of the coal mined. In washing coal as much as 10 or 15 per cent. of combustible matter is sometimes removed, to get rid of less than that per cent. of ash. The coal could be improved in quality nearly as much by the simple expedient of removing 3 per cent. of dust, such as would go through a 20-mesh screen.

Another test, not directly bearing on the value of the fuel, was made to determine the efficiencies of fire beds of different thicknesses. As these tests were all made on chain-grate stokers, it was an easy matter to regulate the thickness of the fire to a nicety. The results obtained are shown in the diagram Fig. 6, the upper curves indicating the horsepower obtained with two different sizes of coal.

To determine the effect of ash upon the value of fuel we conducted a series of tests upon a large and uniform lot of coal. The results are shown in the diagram (Fig. 3). In this diagram the solid curve indicates horsepower and the curve with dashes indicates efficiency. The first test was made with coal containing something less than 10 per cent. of ash, and the successive tests with increasing amounts. When the ash content had been increased to 40 per cent. we could still burn the coal, and the coal would heat the water up to the boiling point, but it would not produce enough heat to make steam. Therefore, coal containing 40 per cent. of ash was absolutely valueless. This curve (Fig. 3) I consider the most interesting and satisfactory of any that we obtained during these tests. Those two curves—one of efficiency and one of capacity—are shown reproduced in Fig. 7, and the curve drawn through them which we have taken to indicate the value of the coal, because coal has one value in proportion to its efficiency and another in proportion to the boiler capacity that can be generated with it. Therefore, with a curve drawn through the other two, we may have the true indication of the commercial value of the coal. The scale on the left is drawn from 0 to 100, 100 being taken as a standard in coal having an ash of 12 per cent.

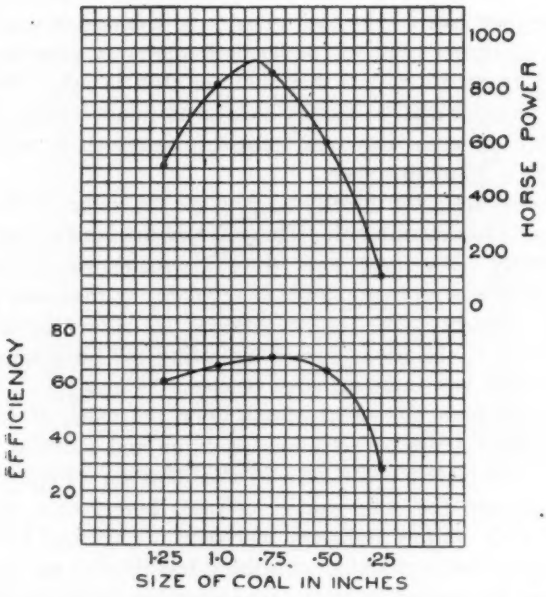



**Fig. 2.**—Effect Produced in Steam Generation by Coal of Varying Sizes.

The apparatus employed in the researches to be considered consisted of two Babcock & Wilcox boilers, one being fourteen tubes high and eighteen wide, of approximately 5,000 square feet of heating surface, fitted with a chain-grate stoker of 75 square feet in area, which discharged the gases of the fire from under an ignition arch 5 feet long, immediately among the tubes of the boiler. This boiler was also fitted with a Babcock & Wilcox superheater, having an approximate area of 1,000 square feet. The other apparatus employed in one of the series of tests differed only in sizes; its boiler was twelve tubes high and sixteen wide, contained 4,000 square feet of heating surface, provided with a superheater, and served with a chain-grate stoker of 66 square feet in area. Fig. 1 is a sectional elevation of the larger boiler.

INFLUENCE OF ASH IN COAL ON CAPACITY AND EFFICIENCY.

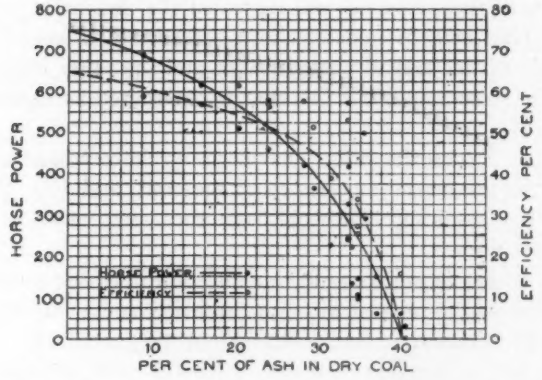



**Fig. 3.**—INFLUENCE OF VARYING PERCENTAGE OF ASH IN IN COAL.

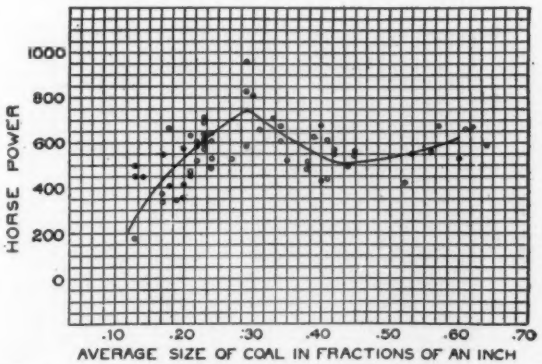



**Fig. 4.**—EFFECT OF SIZE IN COAL SCREENINGS ON CAPACITY PRODUCED.

Fig. 3 gives results of eighteen tests made to determine the effect of varying quantities of ash associated with coal.

Figs. 4 and 5 illustrate the result of sixty-two tests. With each the size of coal as measured by screens with square openings ranging in dimensions from 0.25 inch to 1.50 inch, advancing by 0.25 inch, and the average sizes of coal, as shown

at the base of the diagrams, were calculated from sizing tests made with these screens, and represent the dimension in fractions of an inch of openings in a screen which would allow one-half of the coal to pass through and the other half to go over the screen, and it is this that is designated as its average size.

Fig. 4 shows the effect produced on horsepower output, owing to this variation in size of the coal, and Fig. 5 illustrates the resulting efficiency from the same cause and for the same tests.

The curves of efficiency in this diagram illustrate a constant heat efficiency produced through the boiler for a full working range in thickness of fire, insuring not only maximum excess of air, but incomplete combustion loss as well, yet efficiency remained uniform, and the only opportunity for the "skilful" and "intelligent" fireman is in selecting that thickness best suited to capacity requirements.

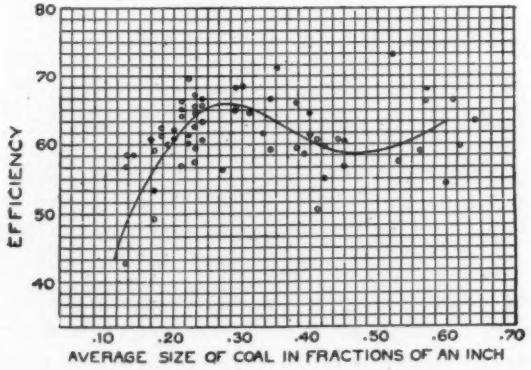



**Fig. 5.**—Effect of Size of Coal Screenings on Efficiency Produced.

The coal used in these two series of tests was very uniform in size and ash content, and for these reasons was well suited to the purpose of the experiments. In the series with thickness of fire, from 4.5-inch to 8.5-inch, what is known as No.

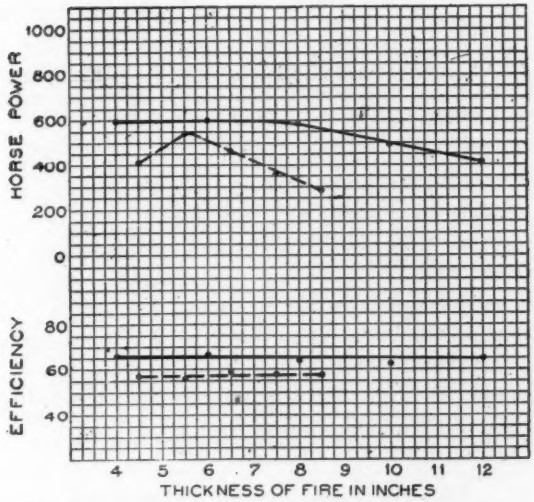



**Fig. 6.**—Showing Uniform Heat Efficiency with Varying Thickness of Fire.

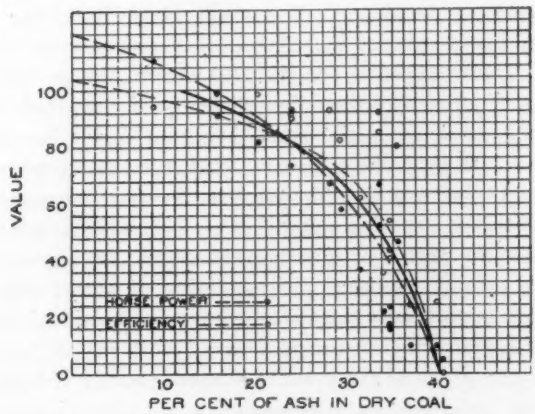



**Fig. 7.**

5 washed coal was used, a size which passes through a screen having round openings 0.25 inch diameter. With the other series and a larger range in thickness, washed screenings were employed.

This paper does not presume to lay down the ultimate laws by which fine coals may be graded in value, but rather to point out the fact that such laws, although at present obscure, do exist, and that our conclusions drawn from numerous tests are as herein indicated.

During the year 1905 there was produced in Illinois and Indiana about 50,000,000 tons of coal, 40 per cent. of which was 1¼-inch screenings, and, although it was not in every case separated from the lump, we can truthfully say that this 40 per cent., or 20,000,000 tons of screenings, was sold at the mine at an average price not to exceed two-thirds of its cost of production, and this same fine coal was used for making steam at an average efficiency of less than 50 per cent.

These two facts are sufficient warrant for further investigation of this little known subject.—"Page's Weekly."

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### THE POSITION OF THE SUBMARINE.

The building of very big warships enhances the value of very little warships; and that brings to the fore the policy of constructing submarines. If a small, cheap boat, like a submarine, stands as good a chance of bagging a two-million-pound *Dreadnought* as she does of exterminating a one-million-pound *Majestic,* then the efficiency of the small boat is distinctly advanced. So much being evident, the question remains: What is the chance? That it is considered to be an increasing one may be gathered from the fact that every first-class Power is devoting greater attention to the acquisition of a satisfactory design of submarine boat; and shows more readiness to provide money for the building of such craft. It is therefore opportune to consider the whole question in connection with the details of the past year's work in our own Navy and of the great advance lately attained, as a consequence of research work, in propelling machinery for submarine use. We have in commission, or in course of construction, over forty submarines; but in view of the activity of foreign Powers it is more and more to be regretted that our Admiralty reduced the number to be laid down during the current financial year from

twelve to eight, and the facts since disclosed strengthen the objection to this course which we expressed at the time.

Our chief rival in the possession of weapons for submarine warfare is France. The French Government were ahead of us in adding submarine boats to the navy of the Republic, and now holds the superior position so far as numbers are concerned. According to an Admiralty return, France had thirty-nine submarine boats completed last spring—as against our twenty-five—and fifty building, or projected, as against our twenty-three. Some of the French boats appear, on paper at any rate, far more powerful than our own. Thus the French had eighteen boats in construction, of a displacement of 391 tons, each fitted with no less than seven torpedo tubes; whilst there were six others under construction, each of 383 tons, and having six torpedo tubes. Our own boats of the "C" class, of which there are eleven building, are of 313 tons, and have but two tubes each, although they each carry four torpedoes. There is every probability, however, of a considerable increase in the size and power of the new British boats.

The British fleet of submarine boats has, however, the great advantage of being composed of homogeneous groups, whilst the French vessels are a very mixed collection. How far this would affect tactics in this entirely new field of warfare it is difficult to say, but it is probable that it would have a considerable influence. The original idea of operation with the submarine boat was that a single one would creep out and catch the battleship or big cruiser unawares. The same theory was held when the torpedo boat first came to the fore, but it was speedily found to be ill-founded; both maneuvers and the small amount of war experience that has accrued having shown that attack in group is the proper maneuver. Of course, if the torpedo boat could make reasonably sure of surprise and of the trustworthiness of its weapon, the single-unit attack would be the most profitable; but concealment until within torpedo range is by no means to be depended upon; and thus when attacking in groups a second or third may get its blow home while attention is being devoted to one or two others.

With the submarine the details are different, but the ultimate principle is much the same. The submarine has a means of concealment denied to the torpedo boat, but she is very much slower, and when she takes advantage of her means of concealment, by submergence, she cripples her power of attack enormously in some respects. It may be concluded that no belligerent vessels during any future war will lie at anchor, unless in a well-protected harbor, or in waters so far distant as to preclude the possibility of submarine attack; we have, therefore, only to consider maneuvers under steam. An American naval officer, who has made submarine vessels a study, has said that "the submarine, *when within torpedo range*, is superior to the battleship, since the battleship is vulnerable to the torpedo—the weapon of the submarine." This writer, Lieutenant Halligan, does well to emphasize the words he put in italics; but even when within torpedo range the submarine has not victory assured. Torpedoes fired from a submarine do not always hit their mark, although the application of the gyroscope has done wonders in adding to their trustworthiness. A British boat having four torpedoes on board, or a French boat with seven tubes—we are not aware how many torpedoes the latter vessels carry—might have a further chance; but unless the torpedo were to be fired at random, the boat would have to come to the surface again to sight for a second shot, supposing the ship had not, in the meantime, steamed out of range.

In order to make an effective attack upon a ship under way, it is necessary that the submarine boat should intercept the vessel in her course. The legend surface speed of the "C" class of British submarines is 13 knots, and their submerged speed for 3 hours is put down at 8½ knots. These are really remarkable rates of traveling for vessels handicapped in the manner submarine boats necessarily are, but it is anticipated that the "D" class will make 15 or 16 knots on the surface and 9 knots submerged. Some of the forthcoming French boats have been assigned 13 knots and 8 knots respectively for surface and submerged speeds, whilst the two most recently

projected vessels are intended to have 15 knots and 8 knots; but the designs are not yet complete.

We will suppose, however, that a submarine boat has reached the 14-knot and 9-knot standard. If the boat were to sight a hostile ship approaching directly towards her at 16 knots when at a distance of 4 miles, it would take a quarter of an hour for the ship to reach the submarine, supposing the latter to be stationary. That would be a piece of great good luck for the submarine, and, though it might occur, the probability is hardly great enough for it to be depended upon. We will suppose, however, that, in place of the boat being right in the enemy's path, the ship is steaming on a course that would pass the position occupied by the submarine at the time of sighting at a distance of 2 miles, the distance at which the ship was discovered being again 4 miles. The submarine would have her enemy as she sighted her 30 degrees before the beam. To take a simple case: if the boat, traveling at 9 knots, made directly for the course the ship was pursuing, it would take her rather more than 13 minutes to do the 2 miles which would bring her to a point cutting the ship's course, or, say, nearly 13 minutes to come within torpedo range. In the meantime the ship would have been occupying about the same time to cover the 3½ miles that would lie between her first sighted position and the point where the two would meet. Under these circumstances, the submarine would be within striking distance, and able to fire one torpedo.

The tactics are not necessarily those that would be pursued, but the original conditions supposed are favorable to the boat; that is to say, the luck would be in her favor. No time has been allowed for her filling her tanks to assume the submerged position, and she is supposed to have maintained a direct course. What part of the run would be made under water would be a matter for the discretion of the commander, who would be governed by the light and the conditions of weather; but it would be wise to keep the conning tower above the surface as long as possible, because it is difficult to keep an object in sight by the periscope, and also extremely difficult to judge

distance. The conning tower awash, however, makes the position of the boat visible by the wave it creates—a more noticeable thing than the tower itself in some states of the sea and atmosphere, when the boat is traveling at high speed.

In ordinary daylight the ship would be seen by the submarine at a greater distance than 8 miles, but it must be remembered that, even when the boat is highest out of water, the deck is elevated only a few inches above the surface. Standing on the top of the conning tower, a man would have a horizon distance of not much more than 3½ miles, whilst a height of 50 feet gives only slightly over an 8-mile radius. In daylight, however, there would be a greater chance of the submarine being sighted; and in that case the ship would alter her course so as to avoid the slow-moving submarine; for at present it is doubtful whether any effective means have been devised for a counter attack on these boats when they are below the surface. The most promising suggestion has been the use of small torpedoes with light charges, sufficient, however, to fatally damage so vulnerable a structure as a submarine boat. As they would deal with slow craft, these torpedoes need not be so fast as those used for swifter ships. They could be carried by boats and easily handled. Of course, there is the chance of going over, as well as under, the submarine, even if her position were known; but the torpedoes would be comparatively cheap, so that a fair number might be expended; and if the submarine had been sighted and were known to be attacking the ship, her position could be very fairly estimated, as her lack of speed does not give her much choice. The value of torpedo boats, destroyers, and pinnaces to act as vedettes for discovering submarines and attacking them with quick-firing guns, or with light torpedoes, will be understood. Even if the small craft could not injure the submarines, they might prevent them from coming up to take observations, and thus frustrate their object.

The improvements in the design, and consequent advance in efficiency, of the submarine boat has been a remarkable feature of recent naval history. The various naval authorities con-

cerned have, however, so well kept their secrets that there is not much to say on the subject. At the meeting of the American Society of Naval Architects and Marine Engineers, held in New York last month, an instructive paper on "The Development of Submarines" was read by Mr. L. Y. Spear, a member of that society. In this paper are given some interesting particulars of a trial of the submarine *Fulton,* as carried out by the United States Navy Department last June. The *Fulton* was of the *Adder* class, but has been somewhat altered and much improved in detail since she was built. The *Adder* is a single-screw boat, with the usual gasoline and electric means of propulsion. She is 64 feet long by 11 feet 9 inches beam, and displaces submerged 122 tons.

The program was for the *Fulton* to leave Newport Harbor and proceed at full speed in the light condition to a stakeboat anchored in the open sea. She was there to submerge and find a target 10 nautical miles distant to seaward. This target consisted of two ships' cutters 300 feet apart, and marked by a yacht 250 yards west of the target. All observations during this attack were to be made by the periscope. As it was feared torpedoes might be lost, the *Fulton* was simply required to expose her periscope within torpedo range, and then, submerging the periscope, to pass through the target. She was then to return submerged and pass round a stake boat three miles distant and again attack the target, this time making observations from the conning tower only, the eye-piece of the periscope being removed. She was then to return submerged over the course, pass to the light condition, and proceed under her main engines, charging batteries while under way. After charging batteries she was to remain submerged for 12 hours. The whole trial was to continue for at least 24 consecutive hours, during which the vessel and crew were to be entirely self-sustaining.

These were the conditions laid down, and the *Fulton* more than fulfilled them. She was submerged 15½ hours out of the 24; during the remaining 8½ hours she was cruising on the surface. During the 12 hours' continuous submergence the full crew and one observer were on board, and no fresh

air was supplied until the end of the test. The average depth maintained during the attack was 20 feet, which was sufficient to entirely submerge the periscope. During the 10-mile run to the target the periscope was momentarily exposed at intervals of about 2 miles; the boats, on account of their small elevation, were difficult to pick up. The final observation was made at a distance of 825 yards from the target.

These particulars of an interesting trial give a very fair account of what a submarine boat can accomplish. How the trials of our own craft would compare with the run of the *Fulton* we have no means of knowing. There is little doubt, however, that the submarines of the Royal Navy are second to none, and are probably in advance of all others.—"Engineering."

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## THE COALING OF WAR SHIPS.

Some coaling experiments of considerable value have been recently conducted by the Admiralty in the Mersey. His Majesty's ships *Vengeance* and *Cornwallis,* on the 28th of November, last, shipped between them about 1,900 tons of coal at Liverpool. The object of the test was to obtain reliable information concerning the facilities of this port for coaling operations, and it appears that the results obtained are satisfactory to the Admiralty. It was intended to ship 1,000 tons on either vessel, but the coal for the *Vengeance* being short, that vessel took on board only about 904 tons. This vessel was coaled by Clarke's patent automatic barges, one being employed on each side of the ship. The operation was completed in 4¾ hours, or at the rate of over 241 tons per hour, or about 121 tons per hour per barge.

The barges with which these satisfactory results were obtained are fitted with bucket elevators working along the bottom of the barge and up into small towers. The barge is provided with a false bottom. taking the form, therefore, of a large hopper, into which the coal is charged from the railway trucks at the wharf. In the bottom of this hopper are a number of slides, and on these being opened the coal falls into the buckets immediately beneath, which travel in the space

between the false bottom and the hull proper of the barge. The full buckets, containing about 5 cwt. of coal apiece, are weighed automatically, and the weight registered. The coal is then tipped into adjustable chutes leading to the bunker hatches or ports on the vessel to be coaled. The operation is practically continuous, and a special feature of the device is that the control of the coaling operations is practically in the hands of one man. The crew of the barge all told only number about six men, so that labor is practically reduced to a minimum.

When it is further added that the recent operations were handicapped by want of trimmers, and that, had sufficient labor of this class been forthcoming, the 904 tons would probably have been transshipped in about 3½ hours, it will be realized at once that this system of coaling is at once rapid and economical. The further trouble of obtaining some 400 or 500 men for ordinary coaling operations is obviated, and the possibility of delay due to lack of labor thus reduced to a minimum. The barges seem to go far towards fulfilling two of the most important conditions concerning the coaling of vessels of war—namely, readiness and prompt discharge.—"Engineering."

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## GERMAN REGULATIONS FOR GAS-ENGINE TESTS.

The German Associations of Engineers, engineering firms, and large gas-engine builders have issued a series of rules and regulations which are to govern in future the efficiency and output tests of gas engines and gas producers. These are given in detail in the "Zeitschrift des Vereines Deutscher Ingenieure," and their object is to render uniform the conditions under which tests of this class of installations are carried out, with a view to obtain results comparable with other results obtained on the same basis throughout the country. The regulations state the points on which the tests are to bear, both as regards producers and gas engines. The number and duration of the tests would vary according to their purpose, and they are to be planned and agreed upon beforehand, after tak-

ing into consideration the type of plant dealt with and its conditions of working; in the case of tests of special importance made with a view to the final taking over of a plant, or with reference to deductions or premiums, the interests involved are also to form a point for consideration. Tests for taking over a plant are to be made as soon as possible after the plant has been started working; the builders, however, will be given a stated time for private tests, and for effecting final improvements. The extent of this time and other conditions are to be fixed in the contract. For ascertaining the fuel consumption of gas producers the test has to last over eight consecutive hours without interruption. For establishing the consumption of liquid or gas fuel, with a constant load on the engine, tests of about one hour's duration are sufficient at the high loads; should results at low loads have to be ascertained also, tests of a lesser duration would be sufficient. In order to make sure that an engine is working under constant conditions, the temperature of the cooling water as it leaves the engine is to be measured at intervals. Once commenced, the tests have to continue without a break.

With a view to determine the efficiency of an explosion engine, tests of shorter duration under constant load are sufficient, but at least ten series of diagrams are to be taken. For investigations of particular importance, two tests following each other are to be carried out; and these will only be reckoned as valid when they have not been interrupted, and when the results of the two compared show only slight differences attributable to errors in readings. The average between the results of the two tests will be taken as final.

The allowances on output and consumption are to be fully agreed upon before the tests take place, either in the contract or when the test conditions are being drawn up. Should no special agreement have been arrived at on these points, the contract will be reckoned as fulfilled if the figure yielded by the tests is not more than 5 per cent. below the figure promised. But this allowance is only to apply to the maximum, and not to the regular normal output. The figure for the latter must under all circumstances be attained.

All indications with reference to pressure are to state whether absolute or not; temperatures are to be in centigrade degrees. For the mechanical heat equivalent the value $427\ m\ K\ g$=one calorie heat equivalent will be used, corresponding to one horsepower-hour = 632 calories.

The regulations enter into details with regard to the measures to be taken in carrying out the tests. The weighing of the coal and the taking of samples for analyses are also minutely stated. The reports showing the results of tests made are to give the type of plant, its working conditions, principal dimensions, the speed under various loads, when running light, and the variations in speed under a constant load, the method followed in recording the effective power, and so forth. The heat value of gases which do not contain heavy carburetted hydrogen can be calculated by formula should the determination by calorimeter not be practicable. The means for obtaining and recording volumetric measurements of the gases are also entered into.

The committee who have had charge of the preparation of the regulations in question include prominent German gas-engine builders and professors, among whom are Mr. E. Körting, Jr.; Mr. Richter, chief engineer of the Nuremberg Gas-Engine Works; Mr. Stein, Director of the Deutz Works; Dr. Stodola and Dr. Th. Peters, the latter Director of the Verein Deutscher Ingenieure.

All the clauses, their working, and their object, are fully explained by an appendix.—"Engineering."

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## GAS ENGINES AND MARINE PROPULSION.

From time to time, as advances are made in gas-engine practice, the question of the use of such engines for marine propulsion is raised. As one difficulty after another is removed by improvements or new systems, we reach a stage nearer the goal. It is evident that sure advances are being made in the right direction, but the difficulties still are many, and the steps somewhat small and slow, compared with the distance to be traversed. For instance, we take up a paper—plenty of

them have been submitted to societies and institutions—and read about the application of gas engines to ships. We hear of schemes for sets of engines capable of developing 3,600, 5,000 or more horsepower, and all sounds well; but we also know that the largest amount of power yet installed in the form of gas engines on board ship is only a mere fraction of these amounts. For this discrepancy there must be good reason, especially as the names of many able men are connected with the study of this problem.

The chief difficulties encountered in this matter arise from the necessity for any system of marine propulsion being adaptable to a large variety of circumstances, and, if the expression may be used, elastic in nature.

In the matter of fuel the system chosen must be suited to the supply obtainable in all parts of the world. In the matter of power it is necessary that there should be a wide range for working under all conditions of weather and circumstances; and in the matter of handling, the engines should be prompt and easy to reverse, and, in fact, perform all the duties at present carried out by steam. With regard to the first, it is futile to equip a vessel with a gas-producer plant using anthracite. The only fuel possible is bituminous coal, and that, too, in extremely variable qualities. But the producer must be prepared to use these different qualities with, at least, something approaching success. We are told that producers for bituminous coal have now been successfully designed, in which the various accessory appliances are either simplified or altogether abolished. Others have suggested the provision of coke-burning producers, the coke being made on board; this, however, usually being condemned as too cumbrous. It is by no means improbable that this producer difficulty, as well as others, will be surmounted. The subject is making rapid strides, and will no doubt develop to a degree which it is at present difficult to gauge.

Given a successful producer capable of using any grade of bituminous coal, there still remain such difficulties as reversing and reduction of power. This problem has been attacked in

several ways, but with results as yet not wholly satisfactory. Indeed, the choice at present rather falls upon that which is the least crude rather than that which is best. Reversing may be done by the propeller, but this only with small vessels; or it may be managed by rotating the cam shaft. Again, by adding considerably to the equipment it may be managed by electrical driving, or the result may be attained by the system suggested by Mr. J. T. Milton, M. Inst. C. E., in his recent paper before the Institution of Civil Engineers. Again, a suggestion has been put forth by Mr. A. Vennel Coster, in a paper before the Manchester Association of Engineers, that, with three sets of engines, in order to reduce power or bring a vessel to rest, one screw might be reversed while the other two still went ahead, and so on.

In the electrical drive, in which a gas engine drives a dynamo connected up to a motor on the propeller shaft, the horsepower of machinery to be paid for is three times that required to drive the vessel. In Mr. Milton's system of separate engine and compressor, with the example he gives of a 3,250 indicated horsepower engine, compressing gear requiring about 1,450 horsepower is necessary. Thus the machinery paid for amounts to 6,150 horsepower, while the net output of the installation is 3,250 horsepower. Of course, the propelling engine, being on the two-cycle system, would be relatively cheap. Machinery comprising eight or eleven cylinders, together with all moving parts, &c., does not impress one favorably. Mr. Milton's plan includes three expansion cylinders 25½ inches in diameter for the propelling engines. For the compressors two double-acting air cylinders 31 inches in diameter and two double-acting air cylinders 18 inches in diameter for the first and second stages of a two-stage compressor may be chosen, this being driven by a four-cylinder tandem gas engine, of cylinders 24½ inches in diameter. As an alternative, it is suggested to complete the second stage of the compression in one cylinder, 25 inches in diameter, instead of two of 18 inches, and to drive the compressor, a tandem two-cylinder engine, cylinders 34½ inches in diameter.

Mr. Vennell Coster's system appears to us no less unsatisfactory. His proposal certainly involves no large auxiliary plant of compressors and driving engines; but to keep engines going full speed ahead and to counteract their effect by running other engines full speed astern seems a most unmechanical method of surmounting these difficulties. It is probable that the efficient reduction of mean pressure may be attained by fairly satisfactory methods, this being possible by Mr. Milton's plan, and, it would appear also, by certain other means. The chief difficulty, of course, in this is in the fact that the poor mixtures are difficult to ignite. With tandem vertical cylinders 50 per cent. reduction of power is possible by cutting out certain cylinders. Reduction of power below a certain point renders the engine liable to stop, no flywheels, or only very small ones, being possible in marine work.

A further difficulty which presents itself to the economical mind is the use to be made of gas from the producer when the engines are not required. On ceasing to draw gas for the purpose of running the engines, the temperature of the producers must be maintained by continuing the gas production. Something must be done with this. Mr. Coster uses it by running his engines at full speed, one counteracting the others. Mr. Milton makes no suggestion on this point, and we presume that that not required for driving his compressor plant would be allowed to run to waste.

Altogether, the problem is one full of knotty points. Although we are talking airily of installations of many thousands of horsepower, and are only building a few of a few hundred, and while the difficulties that suggest themselves at present appear, on present knowledge, difficult to surmount satisfactorily, we do not doubt that as progress is made, these will all disappear one after another. There is quite possibly a great future before this form of propulsion for marine purposes, but it would seem to be well to be not too ambitious till matters are a little more advanced. The two branches of the subject of producers and gas engines are, as yet, not far advanced even in land practice, and experiment in marine work

might well seem more advisable in schemes of moderate size than on the lines recommended by many recent writers on the subject, whose great aim appears to be mainly to obtain (on paper) some combination of cylinders capable of giving so many horsepower.—"Engineering."

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### A NEW ERA IN YACHT DESIGNS.

We have given this article the above somewhat comprehensive title, because the new measurement rule of the International Conference and the recent appearance of "Rules for the Building and Classification of Yachts," published by Lloyd's Register of British and Foreign Shipping, do actually promise that yacht designing will, in one department, assume a new and healthier character than it formerly did. Yachting has two characteristics: it is a sport, and it is a pastime. Under the former term are included all speed competitions; the latter describes cruising voyages. When sport and pastime can be enjoyed in the same vessel, the yachtsman gets the maximum amount of pleasure for his expenditure. It may further be stated that good sport may be obtained from vessels of honest design and wholesome scantling, even though they may take a minute or two longer over a given course than they would do if they were more flimsily built. For a long time flimsiness was the bane of yachting—that and lack of habitability. Committees and conferences have striven, by means of measurement rules, to bring shape within reasonable limits; but scantling has been too thorny a subject to be tackled, except in a very rudimentary manner in the case of small vessels. Glancing at the voluminous tables Lloyd's have now issued, one ceases to wonder at this reticence.

Our readers will remember that last January an International Conference on Yacht Measurement was held in London, for the purpose of arriving at an international rule of measurement which would give sufficient latitude to the designer to show his skill, yet would prevent the production of vessels which are simply racing machines. Whether the end will have been attained has yet to be proved; for the most knowing

of our yacht designers have become so skilful in the gentle art of tonnage cheating that there is no telling when they are cornered. The rule adopted is expressed by the equation:

$$(L + B + \tfrac{1}{2}G + 3d + \tfrac{1}{3}\sqrt{S} - F) \div 2 = \text{Rating in linear units,}$$

where $L$ = length, $B$ = beam, $G$ = girth, $d$ skin-girth—chain-girth (*i. e.*, girth difference), $S$ = sail area, and $F$ = free-board; the units being either feet or meters. It will be seen that length, breadth and girth, together with sail area, form the taxable elements of the rule. To secure a habitable roomy vessel $d$ is introduced, as it will have the effect of handicapping excessive hollowness of bilge. The minus sign before $F$ indicates a premium on freeboard, though not a considerable one by any means.

There is one other important feature in the rule. The length $L$ has formerly been measured on the water line, a fact which is largely accountable for the exaggerated overhang characteristic of modern racing yachts. No yachtsman, we think, except, perhaps, a few unballasted enthusiasts, will deny that these extravagant shelving ends are of the nature of excrescences. Anyone who has thrashed to windward in a latter-day racer, wind against tide, will bear witness to that. The old "plank-on-edge" yachts—the "lead-mines" of the Thames rule that held sway for so long—had their faults; but they would lie-to easily and with safety, and did not pound in a head sea like the big drum of a brass band.

A vessel with a long counter and a far-outreaching bow with considerable flare had this advantage as a tonnage cheater, that the water line was short when she was upright, but as soon as she heeled to the breeze the overhanging side became immersed, and added greatly to the virtual length of the hull, besides placing the center of buoyancy more to leeward. For these reasons one of the chief aims of the yacht designer was to get as much overhang as possible. This was carried to an extent undesirable for vessels designed to sail in the open sea, although less objectionable in smooth water.

It will be evident that without a considerable flare, or in-

crease of beam above water, the chief advantage of overhang would be lost; and the problem, therefore, was to tax flare to an extent that would check its abnormal development. It was some time before any means to this end, without unduly crippling design, was produced; but ultimately an admirable suggestion of a Danish naval architect, Mr. Benzon, was adopted at the Conference. His plan was to measure the girth of hull from deck to deck at the water line ending, to deduct from that twice the freeboard (a vertical measurement) at the same station, and to add the result (the difference between skin measurement and twice freeboard) to the water-line length. So far as can be judged by forecast, the principles involved in these two factors, the girth difference *d* and the handicapping of overhang at the water-line endings, should lead to a more wholesome and shipshape form of hull; whilst the inclusion of girth will tend to put a check on the exaggerated fin keel that appears as a deformity when a vessel is seen out of water, and which is a source of danger if she touch the ground. It must be acknowledged, however, that the fin enables lead to be carried low and gives quickness in stays.

The factors in the rule that we have named, including the tax on sail area, not only tend to produce a more efficient vessel in nearly everything except, perhaps, in mere speed, but they also incline to economy; the exception to the latter condition being the allowance for the factor *F*, freeboard, which, it will be seen, has the minus sign before it. Very few things, however, are better worth paying for than freeboard. In the Yacht Racing Association rule, to which we shall make reference later, freeboard is not taken into account, but other factors are common to both rules.

There remains one element needed in the composition of a yacht that should be a judicious compromise between an extreme speed craft and a comfortable cruising vessel; something neither a racing machine nor yet a kind of sea-going houseboat. The element referred to is strength of structure. Hitherto, whatever may have been attempted in the way of measurement rule towards producing a more desirable vessel

has been, as we have intimated, largely neutralized by the craze for flimsiness. We by no means wish to convey by this expression that hulls have been carelessly put together, or that materials have been bad; indeed, the very reverse is true. The trouble has been that builders, in their efforts to secure a low center of gravity, have aimed at putting as much of the total weight of hull as possible in the lead keel; and to this end have stinted material in the top sides and decks. The result has been an extremely expensive hull structure; for the cost saved in weight of material has been a trifle compared to the expense entailed by additional quality, and the extremely careful work needed. Yet, even with all this care and skill the yacht was a very delicate structure, not fit for the ordinary work of a sea-going vessel; whilst some of the least favorable examples were only capable of lasting through a race by being tuned up each time, and by a liberal use of the pump. Such vessels were of little value except as prize winners, and if they failed in this they became completely valueless. Even of the best it might be conceded that their mission was ended as soon as they became outclassed, as they speedily did, by the coming of a more extreme product of the art of measurement cheating.

These conditions tended to make yacht racing more and more a pursuit confined to the very rich, and therefore a decadent sport. Those in such a position as would formerly have enabled them to own and race big vessels were reduced to smaller craft, whilst many of the former small-craft men were driven out of the field. More vessels than one, after a couple of seasons or so, were unable to find purchasers for cruising at any price, and were broken up. A partial remedy for this state of things was the introduction of one-design classes, a number of boats being constructed from a single specification, which had to be strictly adhered to. The system has led to some good sport among the smaller classes, but it has its restrictions. In the first place, owners like to see in their craft characteristics that are not shared by every other vessel. This naturally is more apparent amongst those who

have knowledge enabling them to influence the design; but, in any case, a good yachtsman, by the fact of owning a vessel, has engendered in him something almost akin to parental affection, such, we believe, as has no parallel in the relations between man and any other inanimate object. It is this that accounts greatly for enthusiasm in a sport attended by no small measure of discomfort.

There is strong hope, as we have said, that the new International Regulations will do something towards putting an end to the defects which have been a burden on yachting; and that we may have a return to those more specious days when owners both lived and raced on their yachts; so that a boat, though built for racing, may still be worth something, even if she cannot fly a string of flags at the end of the season. When the scantling question was brought forward at the International Conference of 1906, it was seen that it was too full of complicated detail to be thrashed out by any congress. It was, however, determined broadly that scantling restrictions were absolutely necessary; and by a unanimous vote it was decided that Lloyd's Register should be invited to confer with other classification societies with a view to coming to an "agreement on a uniform rule for the scantling classification of sailing yachts."

Lloyd's accepted the duty thus suggested to them, and the result is the tables to which we have made reference, and which, it is safe to say, nearly every yacht designer has been studying closely of late. The tables, which are in two sets, one for metric and the other for English measurements, give the requirements for wood, steel, and composite yachts for each of the international rating classes from 5 meters (16.4 feet) to 23 meters (75.4 feet) inclusive. As is well known, for nearly thirty years past, Lloyd's have undertaken the survey and classification of yachts, but this has been chiefly confined to the larger craft, especially steam vessels. To have a little boat of 16½ feet built under survey, which will be compulsory if she is to compete in international races, is a new feature, and certainly one that has its advantages. As is

stated, "the constitution of Lloyd's is peculiarly well adapted for the administration of the new rules. Experienced surveyors are stationed in all the yacht-building ports, whose duty it will be, not only to see that the rules are complied with, but also to advise and assist the builders generally in carrying out the new requirements; and very complete instructions will be issued to the surveyors in order to ensure uniformity of practice in the different ports." The regulation, however, has been subjected to much adverse criticism, as it robs the designer of initiative; and there appears to be a general feeling that Lloyd's surveyors will be somewhat too heavy-handed for yacht work.

The scantlings alone occupy seven sheets, some of them containing over fifty columns; whilst the explanatory matter extends over 27 pages. It will hardly be expected we can give even a *précis* of the matter.* Wood, composite, and steel yachts are treated respectively in separate tables.

We have referred to the Yacht-Racing Association rule, and it will be of interest to add a few words about some former methods adopted for handicapping yachts for racing purposes. In the earlier part of the last century yachts were classed by the common tonnage rule, $L \times B \times D \div 96$. Length was taken on the keel, and this led to abnormal rake of stern posts —the earliest record of tonnage cheating—so the Thames clubs adopted a deck measurement, and in 1854 the celebrated Thames measurement was introduced. The formula was $(L—B) \times B \times \frac{1}{2} B \div 94$. Under this rule the great yacht races of this country were sailed for a period of nearly thirty years; and to meet it, until the rule was pressed to an undue extent, many fine yachts were built. The heavy tax on beam, and absolute freedom as to depth, ultimately led to the plank-on-edge model, in which sail-carrying power was entirely dependent on a deep lead keel. The old "lead mines" were, however, very weatherly, and could be depended upon to thrash out from the proverbial "N.E. corner against a S.W. gale," a consideration that was exceedingly comforting towards the

* For the convenience of our readers, we may state that the rules may be obtained by writing to the Secretary of Lloyd's Register of Shipping, 71 Fenchurch Street, the price being 5s. per copy.

end of the season. They were also absolutely safe from capsizing. It was, however, sometimes hard work to hold on on deck; and a race in the smaller classes—say one of the 3-tonners of the 'seventies—might remind one of a frolic on the back of a porpoise.

In 1880 the Yacht-Racing Association brought in a new rule: $(L + B)^2 \times B \div 1{,}730$; beam being again heavily taxed. In 1896 we find a more complex formula, in which girth was introduced. This had been suggested many years previously by Mr. Landseer Mackenzie, a successful amateur designer and Corinthian yachtsman. Sail area was also an element.

The '96 rule was superseded five years later by the existing Y. R. A. rule:—

$$\frac{L + B + \frac{3}{4}G + 4d + \frac{1}{2}\sqrt{s}}{2.1}.$$

In this formula we see introduced for the first time the factor *d*, girth difference, and there are—with the exception of freeboard—the same elements as in the international rule, though differently treated. The important principle included in the modification in the value of *L*, length, introduced at Mr. Benzon's suggestion, is, of course, absent in the older Y. R. A. rule.

Considerations of space prevent us following this interesting question further. We can only refer our readers to Mr. R. E. Froude's able paper, printed in the last volume of the Transactions of the Institution of Naval Architects, and to Lloyd's publications. The "Table of Tax Figures," in an appendix to Mr. Froude's paper, is especially instructive. Its purpose is to assess the tax on various elements, bringing them to a common denomination, and thus to enable a designer to determine to what extent a change in any given element can be balanced by changes in other elements. We give some of the figures below:—

| ..... | *L.* | *B.* | *G.* | $\sqrt{s}$. | *d.* | *F.* |
|---|---|---|---|---|---|---|
| Existing Y. R. A. rule..... | 0.44 | 0.12 | 0.13 | 0.27 | 0.035 | ... |
| Conference rule..... | 0.54 | 0.14 | 0.11 | 0.22 | 0.032 | — 0.038 |

Whether yacht builders will accept with a good grace the restrictions as to scantling to be put upon them by the action of the International Congress is a matter that remains to be seen; and their attitude will largely influence an extension of the legislation. As stated, there has been a good deal of adverse criticism. In some of the smaller classes the scantling is certainly generous in its dimensions, especially in the light of what some of the most successful designers of these craft, such as Mr. Linton Hope, have accustomed us to. However, the smaller classes are not so much affected by international agreements, and there will be plenty of racing outside Lloyd's rules. Whether, or to what extent, the clubs will fall into line with the suggestions now put forward remains also to be seen; but, in any case, the departure is one of great interest, and may prove the beginning of a better era for an uncontaminated form of sport, which, perhaps more than any other, fosters the best characteristics of our race.—"Engineering."

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## BRITISH NAVAL GUNNERY.

A report issued by the British Admiralty, concerning heavy gun practice in the Navy for 1906, gives some interesting figures, and shows a high standard of proficiency. The average points per man have risen from 68.2 last year to 80 this year, and forty-two ships out of eighty-eight that fired were above this average, while no less than fifty-eight were above the average of last year.

The first fifteen ships in order of merit made over one hundred points, and their firing was as follows: The *Drake,* flagship of Prince Louis of Battenberg, 146 hits out of 167 rounds; the *King Edward VII,* flagship of Sir William May, 130 hits out of 148 rounds; the *Cumberland,* 95 hits out of 113 rounds; the *Formidable,* 109 hits out of 130 rounds; the *Hindustan,* 121 hits out of 140 rounds; the *Carnarvon,* 78 hits out of 85 rounds; the *Duke of Edinburgh,* 115 hits out of 132 rounds; the *Exmouth,* flagship of Sir Arthur Wilson, 102 hits out of 138 rounds; the *Venus,* 78 hits out of 96 rounds; the *Hampshire,* 74 hits out of 90 rounds; the *Diana,* 76 hits out

of 99 rounds; the *Majestic,* 100 hits out of 126 rounds; the *Shearwater,* 39 hits out of 49 rounds; the *King Alfred,* flagship of Sir Arthur Moore, 120 hits out of 141 rounds; the *Good Hope,* flagship of Sir Richard Poore, 119 hits out of 147 rounds. Of these fifteen ships, the first in order of merit made 124.49 points and the last 101.44 points.

The *Bulwark,* the flagship of Lord Charles Beresford, made 93 hits out of 118 rounds fired. The second cruiser squadron, under command of Rear Admiral Prince Louis, takes first place in order of merit by squadrons. The score for this squadron averaged 98.7 points per man. The Mediterranean fleet came second, with the *Formidable* as the best ship, the average points per man being 93.5. The third cruiser squadron is third in order of merit, the *Carnarvon* being the best ship, and the points per man 90.8. The Atlantic fleet stands fourth, with the *King Edward VII* leading, and the squadron score at 88.5 points per man.

In the individual shooting some remarkable records were made. Seaman Baker, of the *Drake,* scored eleven hits out of eleven rounds with a six-inch gun in one minute. Scores of eight hits out of eight rounds and seven hits out of seven rounds were frequent with the six-inch gun. Petty Officer Sullivan, of the *Duke of Edinburgh,* made ten hits from ten rounds in one minute and a half with a 9.2-inch gun, and eight hits out of eight rounds with this gun appear to have been common. A petty officer of the *New Zealand,* with a twelve-inch gun, scored nine hits in ten rounds in two and three-quarter minutes, and a marine in the *Bulwark* made ten hits out of twelve rounds.

The Admiralty, in issuing the report, notes its extreme satisfaction at the very marked improvement in the results as compared with former years, including even those of 1905, when the shooting showed so great an advance over previous results. It further notes that this improvement is due to a higher standard generally throughout the fleet.

The report shows that in ten years the percentage of hits per gun per minute has increased with the 12-inch gun, from

.09 to .81; with the 9.2 inch, from .17 to 2.84; with the 6-inch, from .89 to 5.68, and with the 4.7-inch and 4-inch, from 1.83 to 4.98. Every ship in commission took part in target practice in 1906.—"Army and Navy Journal."

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## HISTORY OF THE TURBINE.

Now that the *Dreadnought's* steam trials have proved such a conspicuous success, it is interesting to trace the progress of the Parsons steam turbine from its first trial on the water nearly a decade ago. It is not proposed in this article to deal with turbine installations in vessels other than warships. It will hardly be disputed that the turbine, in its present stage of development, offers much greater advantages to men-of-war than to merchantmen, since there is a vast quantity of mercantile tonnage which the use of turbine engines would not at all benefit. Most readers of the "Naval and Military Record" will remember the interest that was excited by the remarkable speed of Mr. Parsons' experimental boat *Turbinia* at the Diamond Jubilee review at Spithead in 1897. This craft was something like a miniature destroyer in appearance, but could scarcely be classed as a warship.

The first vessel designed for war purposes to be fitted with turbine engines was the British Destroyer *Viper,* launched by Messrs. Hawthorn, Leslie & Co., on the Tyne, in 1899. On her trials she developed power equal to about 10,000 indicated horsepower, with which she attained the remarkable mean speed of 36 knots. The highest speed touched during the trials was 37.13 knots—a record which has not even yet been beaten. The displacement of the *Viper* was 325 tons, her length 210 feet, and beam 21 feet. She was followed by the *Cobra,* launched in 1900 by Messrs. Armstrong, Whitworth & Co. The *Cobra* was similar in most respects to the *Viper,* but 13 feet longer of 30 tons greater displacement. Though she did not quite reach the *Viper's* extraordinary speed, she proved herself faster than any other vessel afloat. Both these destroyers met with an untimely fate. The *Viper* was wrecked

off the Channel Islands during the maneuvers of 1901, her destruction being complete, though, fortunately, it was unattended with loss of life. The same was, unhappily, not the case with the *Cobra,* which was mysteriously lost in the North Sea, within sight of the Lincolnshire coast, while on her way from her builders to the Medway. She disappeared suddenly while steaming through a moderate sea, and no entirely satisfactory explanation of the catastrophe has ever been offered. Conjectures as to the cause ranged from a boiler explosion to collision with floating wreckage, but the theory most generally accepted was that she broke her back through structural weakness; and much ill-informed agitation ensued, both in Parliament and the press. It is to be doubted if this explanation was given much credence in the service.

The most serious result of these two disasters was the temporary set-back which was given to turbine propulsion. The opponents of the turbine were many, and included in their ranks not only those interested in the retention of reciprocating engines, but the professional obstructionists who oppose every new thing as a matter of principle. Had these two vessels, or even one of them, continued afloat and in service, there is no doubt their success would have led to the speedy general adoption of the turbine in the British navy, despite opposition; but the absence of sufficient data as to the value of turbine engines for continuous work at sea caused hesitation and delay in following up the matter. When progress was resumed it was in a more or less tentative manner, and continued so until the advent of the present first sea lord.

The next turbine-engined craft to take the water (again from the Hawthorn-Leslie yard) was the destroyer *Velox,* in 1902. Her dimensions were the same as those of the *Viper,* but the displacement went up to 400 tons. Her indicated horsepower was less, only 7,000, but she managed to reach an extreme speed of 33 knots with it. Her continuous speed in ordinary weather was 27.12 knots.

In 1903 Messrs. Hawthorn, Leslie & Co. turned out another turbine destroyer, the *Eden.* She differed considerably

from her predecessors, being among the first of the now well-known River type. Her dimensions are 220 feet by 23.5 feet. The horsepower developed was about the same as in the *Velox*, but the displacement being 550 tons, the trial speed was less, the maximum registered being 26.3 knots (mean). This was nearly a knot in excess of the contract speed. In heavy weather her design and larger size give her an advantage over the *Velox* in this respect.

So far the Admiralty had been content to confine the turbine principle to destroyers, but they now took a decided step forward by ordering turbines to be fitted to one of the four new cruisers of the Gem class, so that comparisons might be made between sister ships fitted with turbine and reciprocating engines. The dimensions of these four cruisers are 360 feet length by 40 feet beam; mean draught, 14 feet 6 inches, and displacement, 3,000 tons. They were launched in the latter part of 1903 and early in 1904, and trials were run early in 1905. The results of the four-hours' full-power trial are given below:

*Amethyst*, built by Armstrong & Co., 13,000 indicated horsepower; 23.63 knots, mean speed; 9 tons coal consumption per hour. *Diamond*, built by Cammell & Co., 9,868 indicated horespower; 22.1 knots, mean speed; 10 tons coal consumption per hour. *Sapphire*, built by Palmers; 10,200 indicated horsepower; 22.43 knots, mean speed; 11½ tons coal consumption per hour. *Topaze*, built by Cammell & Co.; 10,000 indicated horsepower; 22.25 knots, mean speed; 11 tons coal consumption per hour.

From this it will be seen that the *Amethyst*, fitted with turbines, is more than a knot faster than the best of her sisters, fitted with reciprocating engines, and this, too, at a coal consumption from 1 to 2½ tons less. Subsequent sea service has more than confirmed this result.

These facts probably had a large share in influencing the Admiralty to adopt the bold course (characteristic of Sir John Fisher's régime) of equipping the *Dreadnought*—a vessel six times the size of the *Amethyst* and vastly her superior in

fighting power—with turbine engines. How wise this measure was has been proved by the results of the *Dreadnought's* trials, and there is every reason to hope that the completion of the three great armored cruisers of the *Invincible* class, and of the several fast ocean-going destroyers now in hand, will witness a still greater triumph of the turbine.—"Army and Navy Military Record."

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## FOREIGN NOTES.

As proof of how rapidly war vessels deteriorate, mention may be made of the cruiser *Katoomba,* which has recently been stricken from the British naval list, although she is only sixteen years old, and was supposed to be a fine vessel when she was launched in the last of the 80's. A vessel of 2,575 tons, with a speed of 19 knots, she was very fast for her day; but the naval authorities have come to the conclusion that it was false economy to expend any money in repairing her, and she will be sold for what she will bring. Two years ago a vessel of the same class was repaired at an expense of $46,000. It was then found that she did not come up to modern standards, and she was put on the market and sold, bringing $10,000 less than her repair bill. In another instance, almost $100,000 was expended in repairing a British war vessel, that amount being about a fifth of her original cost, and inside of three years the ship was sold for $27,000, or $70,000 less than had been paid out to refit her. It is evident that the British Admiralty has come to the conclusion that it is far more economical to sell an out-of-date ship for what she will bring than to send good money after bad in a hopeless attempt to bring her up to date.—"Army and Navy Register."

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## THE "EXPRESS" COAL-BAGGING LIGHTER FOR COALING WAR VESSELS IN HARBOR.

The British naval authorities are experimenting at the Devonport dockyard with a new type of coal-bagging lighter for coaling war vessels when berthed or anchored in harbor.

The purpose of the invention is to provide means for filling bags with coal on board the lighter without any recourse to shoveling, and the automatic transportation of these loaded coal bags directly from the lighter to the bunkers of the warship without any handling whatever at any intermediate points. Rapidity in loading has been the object on the part of the designers, and with this appliance there is assured a coaling capacity of 60 tons an hour from each of the two transporters with which the lighter is equipped.

The hull of the lighter resembles that generally adopted for this class of craft. It is constructed entirely of steel and can carry a maximum load of 1,000 tons of coal. It measures 145 feet in length by 36 feet beam and 19⅛ feet molded depth, and has a draught of 14 feet when fully loaded. The hull is subdivided by means of three transverse bulkheads into four main compartments. In the forward compartment is accommodation for the crew; that next aft contains the boiler and steam-raising plant for driving the hoisting mechanism, electric-light installation, etc.; the two center compartments contain the coal. In the center of the craft, at the bottom, is a small reserved space where the hoisting engines, pumping engines, condenser and electric-light plant are placed. Above this area are the air-filtering and ventilating fan chambers. On the deck itself are two vertical towers or elevators fore and aft respectively for conveying the coal from the loading compartments to the warship alongside, while in the center of the deck are two slewing cranes for transshipping the coal from a collier to the lighter itself.

At the bottom of the lighter, extending practically its entire length on each side, and parallel to one another, are two galleries or filling rooms. These are about 7 feet in height, with a sloping crown at either side. On each side of this gangway are ranged benches at a sufficient height from the floor to enable the mouth of the sack when hung up to be just level with them. The crown of the roof slopes over these benches and the coal contained in the compartments above falls by gravity through orifices onto the benches and is raked by the men

into the open mouths of the sacks. Along the edges of the benches where the coal bags are suspended are fitted bag holders which hold the mouths of the bags open to their fullest extent while the men are raking in the coal. In order to prevent the coal from falling onto the floor of the filling rooms, fixed and portable screens are provided.

As rapidly as the bags are filled they are mechanically lifted onto an overhead rail along which they travel to the foot of one of the vertical elevators by means of a reciprocating pawl device. These elevators extend to a height of nearly 45 feet above the deck of the lighter and are constructed of steel with a crow's nest at the top from which the operator can easily follow and control the conveying operations upon the deck of the warship. Hinged to each elevator is a radial transporter arm long enough to reach over the deck of the vessel alongside. This arm has a vertical travel of 30 feet up and down the elevator, so it can be easily adjusted to the most suitable height; furthermore, it is so arranged that it can be turned through a considerable angle. When out of use the arm is packed vertically up the side of the elevator tower, completely out of the way. Each elevator is fitted with a Mackrow-Cameron "Express" transporter capable of lifting 120 tons of coal in bags per hour.

At the top and the bottom of each elevator tower is a grooved wheel over which travels an endless chain provided at intervals with hooks. The bag of coal, upon reaching the base of the elevator, is caught up by one of these hooks and lifted off the overhead rail extending through the galleries and is immediately hoisted by the traveling chain up the interior of the tower until it reaches a predetermined point, where the radial arm projects. It is then automatically released from the elevator chain and directed onto the radial arm, along which it is run to the point on the deck of the warship where it is to be delivered. Trunks are provided for returning the empty bags as rapidly as their contents are discharged to the filling galleries, and the cycle of operations is repeated until coaling is completed.

The two slewing cranes are each of 2½ tons capacity and are of the high-speed Cameron type. They have a maximum overhang of 80 feet from the center line of the lighter, which enables them to reach well over the deck of the collier barge or other craft with ease. Their working radius is any distance between 8 feet and 40 feet, between which limits the loads can be lifted and dumped. In the case of a collier with the coal loose in the hold to be discharged into the holds of the lighter itself, there is a grab of one ton capacity, though they can be utilized equally well in transporting bags of coal from a barge to the lighter or *vice versa* as required, and can if the exigencies so demand assist in the coaling of the vessel already being served by the elevators. The coal drawn from the lighter is shot into the hoppers of the lighter through large hatchways in the deck. Thus while the lighter is coaling the warship alongside, the slewing cranes can be simultaneously replenishing the hoppers of the lighter itself from the opposite side. These slewing cranes are each capable of handling from 50 to 60 tons of coal an hour.

Naturally, while coaling operations are in progress the air within the bag-filling galleries becomes heavily impregnated with coal dust. In order to insure a perfect supply of clean, fresh air within this area the dust-laden atmosphere is withdrawn from the galleries by the ventilating fans, passed through the filtering medium, and fresh air supplied in its stead.

The boat is lighted throughout by electricity, there being some sixty incandescent lamps distributed through the loading galleries, engine and boiler rooms, and the crew's quarters. In order to facilitate coaling operations at night large arc lamps are fitted over the crow's nests on the elevator towers, and communication between the various parts of the lighter is afforded by electric bells and speaking tubes.

It will be seen that the transportation of the filled and the empty bags is entirely automatic throughout, the human element entering only in regard to the filling of the bags.

The bags of coal, upon reaching the warship's deck, are dumped down and wheeled away upon trolleys to the bunkers

by the coaling crew. The designers recommend, however, that two ports be provided in the sides of the battleships through which the radial transporter arms of the elevators can extend and connect with a system of overhead runners fitted on board and attached to the skid beams so as to form a continuous bar. In this manner the bags of coal would travel from the leading rooms on the lighter direct to the bunkers and the contents be there discharged, by which arrangement intermediate handling would be entirely obviated and coaling considerably facilitated and expedited. Furthermore, the decks would be left quite clear, and any necessity of clearing away ship's boats and gear, as is now usually the case when coaling is carried out on war vessels, would be dispensed with.

In the official trials recently carried out by the British Admiralty at Devonport for the purposes of testing the possibilities of this craft both in the coaling of war vessels and also the charging of the lighter itself from barges and colliers moored alongside, eminent success was obtained. In order to test the apparatus to the utmost these trials were extended over a period of four months, and in each trial a new crew for operating the lighter was employed, so that it was impossible for exceptional results to be obtained owing to the men becoming expert with the gear and consequently more expert in its manipulation as a result of continual practice. In the first place, the elimination of the preparations heretofore incidental to the coaling of a warship, such as the removal of boats and davits, etc., was emphasized, since in no instance was it found necessary to disturb the vessel's equipment in any way, the transportation bar being projected through any opening in the ship's side capable of admitting a 2-hundred-weight bag. As the coaling crew became expert in the removal of the bags of coal from the outer end of the transporter speed in coaling was accelerated, and the facility and lighter labor involved in the task was rendered very apparent. The most noticeable feature was the speed with which the vessel could be coaled by this system as compared with the other methods in vogue in

the dockyard, the capacity of the transporter far exceeding that attainable with the other processes.

In the course of the trials seven vessels of varying types were coaled, the quantity taken on board ranging from 1,000 tons for the *Duke of Edinburgh* to 172 tons for the *Monmouth*. In the case of the former vessel the trial extended over six hours, during which time 609 tons were placed on board, the remaining 391 tons being taken on after the trial. The highest coaling speed was attained in shipping 705 tons on board the *Isis*, when 41.75 tons an hour were placed on board from each transporter. In the final trial, in coaling the *Victorious* with 720 tons, the task was accomplished in 5 hours 40 minutes actual working time. Coaling was effected entirely by the transporters themselves without any assistance from the independent cranes. Had the crew been fresh, the work would have been completed in shorter time; furthermore, the men had had but little experience in handling the apparatus. Trials were also made with the cranes for transshipping coal from barges to the lighter itself. On this occasion 580 tons were lifted onto the lighter in 807 trips, the average load each trip being 14.37 hundredweight, or approximately 50 tons an hour. In the official tests of the capacity of the grab 14.84 hundredweight was the average of forty trips.—"Scientific American."

# SHIPS.

## ENGLAND.

**The first-class Torpedo-boat No. 11** (formerly called the coastal destroyer *Mayfly*), constructed for the Admiralty by Yarrow & Co., of Poplar and Glasgow, had her official high-speed trial on March 6, when a speed of 27 knots was obtained during a run of eight hours, the contract speed being 26 knots. The consumption of oil during the eight hours was found to be 21.45 tons—*i. e.*, 2.68 tons per hour. A subsequent trial of 24 hours' duration was made at a speed of 12.11 knots, when the consumption was proved to be 8.79 tons for the 24 hours—*i. e.*, 0.366 ton per hour and 67.65 pounds per knot. On both these trials oil fuel alone was used. Although oil fuel has been tried repeatedly, both in this country and abroad, the Admiralty system is the only one that up to now has proved itself thoroughly successful.

**New Destroyers.**—The Admiralty have placed contracts for the construction of two new ocean-going destroyers, to be named *Saracen* and *Amazon*, which will be larger and more powerfully equipped than the five 33-knot ocean vessels at present building for the Royal Navy. The *Saracen* and *Amazon* are to have a displacement of 893 tons and 888 tons respectively. The *Saracen* is to be built at Cowes, by Messrs. J. S. White & Co., and the *Amazon* at Woolston, by Messrs. Thorncroft & Co. The *Saracen* will have a length of 272 feet and the *Amazon* a length of 280 feet.

The *Saracen* and *Amazon* are each to be equipped with two 4-inch breech-loading guns—the other ocean destroyers being armed with three 12-pounder guns—and will be fitted with engines of 15,500 horsepower, propelling them at a speed of thirty-three knots per hour. They will burn oil fuel, and are to be completed for delivery in 1908-9.

## PERFORMANCES OF NEW BRITISH WARSHIPS DURING THE YEAR 1906.

| Name of vessel. | Type of ship. | Builders of ship. | Makers of machinery. | Displacement. | Type of boilers. | Heating surface. | Grate area. | First 30 hours' trial. | | | | Second 30 hours' trial. | | | | Eight hours' full-power trial. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Indicated horse-power. | Speed. | Coal per I.H.P. per hour. | Water, all purposes, per I.H.P. per hour. | Indicated horse-power. | Speed. | Coal per I.H.P. per hour. | Water, all purposes, per I.H.P. per hour. | Indicated horse-power. | Speed. | Coal per I.H.P. per hour. | Water, all purposes, per I.H.P. per hour. |
| | | | | *tons* | | *sq. ft* | *sq. ft* | | *knots* | *lb.* | *lb.* | | *knots* | *lb.* | *lb.* | | *knots* | *lb.* | *lb.* |
| *Dreadnought* | Battleship | Portsmouth Dockyard | Vickers Sons and Maxim, Limited | 17,900 | Babcock & Wilcox | 55,400 | 1,599 | 5,013* | 13.00 log. | 2.56 | 27.2† | 16,930* | 19.3 log. | 1.7 | 17.01 | 24,712* | 21 25 log. | 1.51 | 15.56 |
| *Britannia*.... | Ditto | Portsmouth Yard | Humphrys, Tennant and Co. | 16,350 | Babcock & Wilcox and cylindrical | 48,291 | 1,483 | 3,539 | 11.44 " | 2.05 | 21.0 | 13,087 | 16.79 " | 1.5 | 16 21 | 18,725 | 18 4 " | 1.83 | 18.55 |
| *Africa* ..... | Ditto | Chatham Yard | J. Brown and Co. | 16,350 | Ditto | 48,396 | 1,490 | 3,682 | 11.8 " | 2.001 | ... | 12,860 | 17.5 " | 1.793 | ... | 18,698 | 19 1 " | 1.872 | ... |
| *Hibernia*..... | Ditto | Devonport Yard | Harland and Wolff | 16,350 | Ditto | 48,648 | 1,476 | 3,710 | 10.4 " | 2.07 | 19.9 | 12,700 | 15.5 " | 1.59 | 17.41 | 18,112 | 18.127 M.M. | 1.92 | 19 66 |
| *Natal*..... | First-class cruiser | Vickers Sons and Maxim | Vickers Sons and Maxim, Limited | 13,550 | Yarrow and cylindrical | 66,836 | 1,298 | 4,913 | 14.18 by bearings | 2.03 | 20.1 | 15,937 | 21 109 M.M. | 1.88 | 17.8 | 23,592 | 23.334 " | 2.21 | 18.47 |
| *Cochrane*..... | Ditto | Fairfield Shipbuilding Company | Fairfield Engineering Company | 13,550 | Ditto | 66,836 | 1,336 | 4,911 | 14.3 M.M. | 2 06 | 19.1 | 16,080 | 21.37 " | 2.04 | 16.4 | 23,654 | 23.292 " | 1.99 | 16.4 |
| *Achilles*.. ..... | Ditto | Armstrong, Whitworth, and Co. | Hawthorn, Leslie and Co. | 13,550 | Ditto | 66,838 | 1,332 | 4,882 | 14 694 " | 1.88 | 19 95 | 16,009 | 21.58 " | 1.85 | 17.87 | 23,968 | 23.5 by bearings | 2.03 | 19.9 |

* Shaft horsepower. † Consumption for ten hours. M.M. = Measured Mile.

**H.M.S. "Gnat,"** the third to be completed of five coastal destroyers ordered from John I. Thornycroft & Co., Ltd., in connection with last year's Naval Program, was launched December 8, 1906, with all machinery on board, from the Company's Chiswick works. The dimensions of the class to which the *Gnat* belongs are: length, 168 feet; beam, 17 feet 6 inches; draught, 5 feet 11 inches; and the contract speed is 26 knots. She is fitted with turbine machinery of Parsons type, built at the firm's Southampton works, and Thornycroft water-tube boilers. The armament will consist of two 12-pounder quick-firing guns, three torpedo tubes.

**New English Torpedo Launch "Dragonfly."**—A forty-foot torpedo launch recently built in England is a most interesting craft, having been designed to operate at a speed of 18 knots. The *Dragonfly* is constructed to carry a 14-inch Whitehead torpedo, which is to be lowered over the side by means of a specially designed side drop gear. The body is first directed bow-on in the direction of the object which it is desired shall be destroyed, and then launched.

This torpedo boat is propelled by a 120-horsepower, gasoline engine, and is of 8,500 pounds displacement, with a draught of 2 feet 7 inches and a beam of 6 feet 2 inches. The boat is built of galvanized mild steel, and is provided with a watertight collision bulkhead. It has a very broad stern, which is said to overcome any difficulty as to stability when launching the torpedo over the side.

A turtle-back deck is arranged in the bow, extending to the rear as far as the after end of the engine, this being a portable piece, carried over the engine to protect it from the weather. Detachable spray guards are so placed as to prevent the splash from the bow waves being carried aboard.

The steering wheel and reversing lever are located on the port side. The engine is supplied with fuel from a tank which holds 100 gallons of gasoline, enough fuel, it is claimed, to operate the launch for a period of ten hours.

The *Dragonfly* is equipped with a four-cylinder engine which operates at a speed of 900 revolutions per minute. The

cylinders are of 8-inch bore and a stroke of 8 inches. The engine weighs about 2,500 pounds, which is at the rate of 23.25 pounds per brake horsepower. It is maintained that there is very little vibration, even at the speed of 900 revolutions per minute, the engine being of very light construction and very carefully and exactly balanced as to its moving parts. This is most essential, in fact absolutely necessary, on account of the very light construction of the hull, in order to insure high speeds and effectiveness in service. The engine is started by means of compressed air contained in a reservoir placed in the stern of the launch. A small Brotherhood compressor is provided for supplying the necessary air pressure, driven by a Thornycroft single-cylinder oil engine of 6-horsepower capacity.

The *Dragonfly* was constructed at the shops of John I. Thornycroft & Company, Limited, Chiswick, near London, where recently very interesting marine gas-producer outfits were constructed and installed in the launches *Emil Capitaine* and *Duchess of Chiswick*.—"International Marine Engineering."

**The Steam Trials of the Armored Cruiser "Warrior."**—H.M. armored cruiser *Warrior* has just completed her official steam trials, with satisfactory results. The *Warrior* belongs to the *Duke of Edinburgh* class of armored cruisers, being the sixth and last to be completed. She was built at Pembroke, and work on her was delayed owing to the withdrawal of the men required in connection with the salvage operations on the *Montagu*.

The ships of this class mark a great advance, not only in the protection aganst attack, but also in gunpowder; each cruiser mounts six 9.2-inch guns in separate barbettes—one on the forecastle, one on each side forward, one on each side toward the stern, and one in the center line on the upper deck aft. Four of these guns may be used on either broadside. There are also in the waist of the ship, on each broadside, two 7.5-inch guns, and the secondary armament includes twenty-six quick-firing guns for repelling torpedo attack.

The machinery of these ships was built to Admiralty design, and practically all the parts, including even the columns and bed plate, were made to standard gauges and jigs, in order to ensure, as far as possible, interchangeability. The main engines were designed to develop collectively 23,500 indicated horsepower, and the high-pressure cylinders were made 43½ inches in diameter, the intermediate cylinders 69 inches in diameter, and the two low-pressure cylinders, each 77 inches in diameter, the stroke in all cases being 42 inches. There are two large condensers to each engine, each having a cooling surface of 7,009 square feet, which serve for the main and auxiliary engines; either may do the work for each set of engines while the other is being overhauled. Some of the vessels have Babcock & Wilcox boilers, while others have Yarrow boilers, for four-fifths of the power to be developed, the remainder of the steam being supplied by cylindrical boilers. This combination, it will be remembered, was suggested by the Navy Boiler Committee, with a view of using cylindrical boilers for low powers. But as this combination has not shown any increased economy, and has involved a certain measure of inconvenience, the practice has been discontinued. The boiler installation in recent ships is entirely made up of water-tube boilers.

The machinery of the *Warrior* was constructed by the Wallsend Slipway and Engineering Company, Limited, and is the most important naval contract completed by them. It marks the progress of this company, which but a few years ago confined its operations to ordinary merchant work, but has, since the apppointment of Mr. Andrew Laing as managing director, stepped into the front rank, a fact indicated not only by the construction of the *Warrior's* engines, but by the order received for the 70,000 horsepower turbine machinery for the Cunard liner *Mauretania,* and still later by the contract for the turbine machinery for H.M. battleship *Superb.*

The first trial of the *Warrior* at one-fifth power was of 30 hours duration, and on this, as on all the trials, the vessel was loaded to the mean draught of 27 feet, while the boilers

maintained a pressure of 168 pounds to the square inch. The cut-off at the high-pressure cylinder was 42 per cent. of the stroke, and the engines, running at 83.2 revolutions, indicated 4,781 horsepower, the coal consumption working out at 2.01 pounds.

**Table I.**—STEAM TRIALS OF H. M. S. "WARRIOR."

| Duration of trial | { 8 hours' full power. | | 30 hours' consumption trial at 15,700 I.H.P. | | 30 hours' consumption trial at 4,700 I.H.P. | |
|---|---|---|---|---|---|---|
| | *Fwd.* | *Aft.* | *Fwd.* | *Aft.* | *Fwd.* | *Aft.* |
| Draught of water, feet and inches | 26-00 | 27-06 | 26-07½ | 27-04½ | 26-07½ | 27-04½ |
| Steam pressure in boilers, pounds per sq. in. | 193.7 | | 186.1 | | 168.0 | |
| Air pressure in stokeholds: | | | | | | |
| Yarrow boilers, inches | 1.1 | | 0.4 | | ... | |
| Cylindrical boilers, inch | 1.0 | | 0.4 | | ... | |
| | *Stbd.* | *Port.* | *Stbd.* | *Port.* | *Stbd.* | *Port.* |
| Vacuum in condensers, inches | 26.7 | 27.0 | 26.9 | 27.2 | 27.0 | 26 6 |
| Revolutions per minute | 137.7 | 137.5 | 121.4 | 121.2 | 83.0 | 83.4 |
| Mean pressure in receivers: | | | | | | |
| High, pounds | 178.0 | 178.0 | 164.3 | 166.4 | 106.1 | 107.7 |
| Intermediate, pounds | 73.0 | 75.0 | 53.7 | 52.0 | 24.1 | 28.3 |
| Low, pounds | 24.0 | 23.0 | 10.5 | 11.3 | 1.0 | 1.5 |
| Mean pressure in cylinders: | | | | | | |
| High, pounds | 65.9 | 72.6 | 68.5 | 71.37 | 30.47 | 30.5 |
| Intermediate, pounds | 35.7 | 32.7 | 27.7 | 25.11 | 10.61 | 12.14 |
| Low, forward, pounds | 18.0 | 18.5 | 12.26 | 12.05 | 5.3 | 5.12 |
| Low, aft, pounds | 19.1 | 19.2 | 12.51 | 12.17 | 5.21 | 4.71 |
| Mean indicated horsepower: | | | | | | |
| High | 2,861 | 3,147 | 2,621 | 2,727 | 797 | 801 |
| Intermediate | 3,900 | 3,567 | 2,668 | 2,414 | 698 | 803 |
| Low, forward | 2,448 | 2,513 | 1,470 | 1,442 | 434 | 431 |
| Low, aft | 2,598 | 2,607 | 1,500 | 1,456 | 429 | 388 |
| Total | 11,807 | 11,834 | 8,259 | 8,039 | 2,358 | 2,423 |
| Grand total | 23,641 | | 16,298 | | 4,781 | |
| Consumption of coal per indicated horsepower per hour, pounds | 2.33 | | 2.07 | | 2.01 | |

The 30-hours' trial at two-thirds power was run in stormy weather, with a heavy sea, and these conditions militated strongly against economy. The air-pressure in the stokehold was 0.4 inch, and the steam pressure at the boilers 186

**Table II.**—MEAN RESULTS OF H. M. S. "WARRIOR'S" TRIALS.

| ..... | At one-fifth power. | At seven-tenths power. | At full power. |
|---|---|---|---|
| Heating surface per indicated horsepower of main engines, square feet | 7.38 | 4.1 | 2.83 |
| Coal consumed per square foot of grate area, pounds | 15.6 | 25.2 | 41.4 |
| Indicated horsepower per square foot of grate area | 7.8 | 12.2 | 17.8 |
| Indicated horsepower per ton of machinery | ... | ... | 10.8 |
| Consumption of water per indicated horsepower per hour (for main engines and auxiliaries) | 21.36 | 18.28 | 19.08 |

pounds. The high-pressure cylinder was slightly linked up, the average cut-off throughout the trial being 60 per cent. Running at 121.3 revolutions the power indicated was 16,298 horsepower, which gave the ship a speed of 20¾ knots, notwithstanding the heavy weather. The coal consumption worked out at 2.07 pounds, and, as shown in Table II, the water evaporated at 9 pounds per pound of coal.

The full-power trial was run on February 2 in favorable weather. The total power developed was 23,641 horsepower, when the engines were making 137.6 revolutions. This is equal to 10.8 indicated horsepower per ton of machinery. The air pressure in the boiler rooms was 1.05 inches. The coal consumed per square foot of grate surface was 41.4 pounds, while the indicated horsepower per square foot of grate was 17.8 horsepower. The average steam pressure at the boilers was 193.7 pounds. The results, which are set out in Tables I and II are therefore satisfactory, all the conditions of the contract being implemented.—"Engineering."

**Oil Fuel for Marine Purposes.**—Mr. Graydon Hume, in a paper read before the Institute of Marine Engineers, gave some useful practical information on the burning of liquid fuel at sea. He dealt with three methods, viz: first, using air as an atomizing agent; secondly, using steam; and, thirdly, atomizing by centrifugal action. The first involves the use of settling tanks, a pumping system, a meter for gauging the quantity of oil, air blowers, heaters, burners, and also a gasoline engine and auxiliary blowers. The main object of the tanks is to separate the oil from water held in suspension, and to this end there are wash plates in the bottom to prevent the water being again mixed with the oil when it has once settled. A steam coil is also fitted for heating the oil to from 100 degrees to 130 degrees Fahrenheit. The pumping system is for conveying the oil from the bunkers to the burners. Three pumps should be employed for alternate use, straining or filtering devices should have careful attention, and there should be an efficient air vessel. It is essential that all piping should be of iron, and not copper. With viscous oils there should be means of heat-

ing the oil in the bunkers; the usual manner being by a few turns of a steam pipe near the suction. Air blowers, generally of the Roots type, discharge into an equalizing pressure tank. The oil heaters are about 10 inches in diameter, and have a copper coil inside about 8 feet in diameter and 6 feet long; either live or exhaust steam can be used. The burners consist of a pipe through which the oil flows, and which is surrounded by a jacket which forms a passage for the air. There are two valves for respectively controlling the supply of air and oil.

The construction of the furnace does not, in Mr. Hume's opinion, get due attention. Complete combustion is impaired by too great a volume of air, and if the temperature of the gases is not sufficiently raised, smoke results, unless the quantity of oil is increased. In early stages of combustion the gases distil at low temperature and pass away unconsumed. Various arrangements of brick-work are used, but all agree that an extended front is necessary, and that the throat of the furnace should be lined. The bottom also should be of brickwork so as to cause any leakage of oil to be burnt. The back and sides should also be lined up to the lower row of tubes. Retarders in the tubes are beneficial. In an example from practice quoted the machinery of a ship developed 2,240 horsepower, and the consumption of oil was 1.08 pounds of oil per horsepower per hour, the funnel temperature being 540 degrees Fahrenheit. From a letter on the subject from a friend quoted by the author the following points may be summarized: Great care should be taken to have clean oil, as anything that will stop the regular flow will cause smoke, and that runs up consumption. The soot, being heavy, can not be blown away by steam, but must be swept; spring scrapers being best. Water can be detected by a "frying" sound. Heaters are essential with an air system, and make a steam system work better. With natural draft. burners should point so as to converge about 3 feet from the burner end; and if draft is admitted below, they should be pointed down at a slight angle, otherwise the entering air drives the flame up against the crown of the furnace. A better way is to allow air to come in from the four corners of the

furnace, as this allows a minimum supply without smoking. The atomizing agent should not be used as a jet to increase the draft. Tubes should be swept every two months at least. Ferrules will stop tubes leaking, and have to be used when boilers are forced; they, however, retard the draft, and are, with small tubes, soon choked by oil soot. The oil pressure on burners should be kept as low as possible—about 15 pounds to 25 pounds—according to the density of the oil. With low pressure the valves can be run almost wide open.

Turning to the use of steam as an atomizing agent, Mr. Hume points out that large evaporators have to be installed to make good the water used. This will vary from 5 to 15 per cent. of the total evaporation. Examples are given of practice at sea with oil fuel with various descriptions of burners, the consumption ranging between 1.26 pounds and 1.48 pounds of oil per indicated horsepower per hour. The mechanical-spray system is described as similar in principle to the form of nozzles used for lawn sprinkling. Pressure is applied to make the oil flow and break it up. The passage of the fluid gives the required rotary motion, spiral blades being fitted for the purpose.

Upon a trial made with a Körting burner of this type, 14.9 pounds of water were evaporated per pound of Texan oil, from and at 212 degrees Fahrenheit.—"Engineering."

**Return of Casualties to British War Ships** shows that during 1905 eleven battle ships were damaged by accidents, the time of repair reaching a total of 580 days, or an average of 53 days apiece. Four armored cruisers were damaged by accident, and the repairs occupied 171 days, or an average of 43 days apiece; eight protected cruisers were damaged, and the repairs required 271 days, so that the average works out to 34 days. One cruiser was damaged and not repaired. Thirty-one destroyers, submarines and torpedo boats were damaged, the time of repairs averaging 43 days. Fifty-eight deaths and 39 cases of injury are recorded as the result of a total of 90 casualties to vessels. Thirty-three lives were lost on the occasion of the battle ship *Caesar* colliding with the barque *Afghanistan*. —"Army and Navy Register."

**The Condition of Funnels of the British Ship "Argyll,"** as the result of overheating when steaming continuously at high speed during the recent maneuvers, has drawn attention to a weakness which has developed in the construction of the funnels of the latest British war vessels, due mainly to a desire to reduce the weights carried. The introduction of the water-tube boiler necessitated an increase in the number of funnels to ensure an efficient draft; at the same time, the heat given off, especially at high speeds, has greatly increased in intensity. Gradually, the number of funnels has been increased to four, while to keep down the weight the thickness of the casing has been fixed at three-thirty-seconds of an inch, and the funnel proper at three-sixteenths of an inch, and herein lies the weakness to which attention is drawn. The comparatively thin funnel plates, when exposed to the fierce heat generated at high speeds, generally erode, and from the experience gained in the *Argyll* and other vessels it is not too much to add that, if exposed continuously, as they would be in actual war, they would inevitably become not only a source of weakness, but of danger also to the ships carrying them. The remedy suggested is to increase the thickness of the plates, at least at the most exposed positions, to one-fourth inch, and we understand this is now receiving the attention of the Admiralty.—"Naval and Military Record."

## EGYPT.

**"Mahroussa."**—An interesting piece of work has recently been completed by Messrs. A. & J. Inglis, Pointhouse, Glasgow, in the reconstruction of the Khedivial yacht *Mahroussa*, the work including the fitting of new boilers and turbine machinery in place of the original oscillating engines, the removal of the side paddle-wheels, and the reconstruction of the stern to suit triple-screw propulsion. The result has been most satisfactory, and the Khedive has himself paid a well-deserved compliment to the firm of Messrs. A. & J. Inglis. The *Mahroussa* was originally built forty-one years ago by Messrs. Samuda Brothers, for Ismail Pacha, and was probably at that date the

largest and most magnificent vessel of the kind in existence. Built with the best materials procurable, and with workmanship of the highest class, she was found on inspection after forty years' service to be much too good for the scrap heap, and sufficiently sound to be worth a complete refit. Sea-going paddle steamers, and low-pressure boilers with simple engines, are now, however, completely out of date, and the preservation of Penn's oscillating engines was not to be thought of. His Highness the Khedive of Egypt, being thoroughly well informed of what is going on in Western Europe, at first determined to have the *Mahroussa* transformed into a twin-screw steamer, and later, realizing the progress of the turbine, resolved to avail himself of the new motor. Messrs. A. & J. Inglis, Limited, of Pointhouse, Glasgow, had built for His Highness the 700-ton yacht *Safa-el-bahr,* which gave him the greatest satisfaction, and earned for Dr. Inglis the decoration of Commander of the Imperial Order of the Osmanieh, and as a consequence of the success of this yacht, they were asked to submit plans and estimates for the work to be carried out on the *Mahroussa* to Sir Vincent Corbett, K. C. V. O., the Financial Adviser to the Khedive, who called to his assistance Professor Biles, of Glasgow University, and, after some negotiations, the plans on which the alterations have been carried out were arranged.

The chief constructional work, so far as the hull was concerned, was asssociated with the adaptation of the stern to the triple-screw arrangement. This had to be carried out in a graving dock, and practically the only docks available for Messrs. Inglis were those of the Clyde Navigation Trust at Salterscroft. The trustees occasionally show some hesitation in granting the use of these docks for any lengthened period, as they are constantly in demand for cleaning and painting operations and urgent repairs to vessels frequenting the ports. It happened that an Allan liner, which had sustained serious damage, required a dock concurrently with the *Mahroussa,* and Messrs. Inglis were therefore urged to make their occupancy of the dock as brief as possible. To meet the Clyde Trust con-

dition, Messrs. Inglis devised special methods, so that the yacht would occupy the dock for the minimum of time. Molds were made of the frames while the vessel was afloat, and as much of the after-body as had to be reconstructed was laid down full size in the mold loft. From this draft the new stern frame, keel piece, balanced rudder, bossed frames, etc., were completed, ready to be erected as soon as the vessel was docked and the old stern cut away to receive the new. Every single piece of the new construction was found to fit so accurately that when the job was completed there was nothing to show that the vessel had not been originally built as a triple-screw steamer. The engines and boilers had meanwhile been removed, the paddle boxes taken down, and the poop and deck-houses, as well as most of the decks, removed, bulk-heads shifted, bunkers rearranged, and new engine and boiler seats fitted. Steel decks were laid for about half the length of the ship. A range of deck houses, framed in steel and lined with polished teak, was erected on the upper deck, which was relaid with teak.

The new machinery, including the turbines, was constructed by Messrs. A. & J. Inglis, of Glasgow. It is the first work of the kind undertaken by the firm, and the success attained on the trial, on the voyage to Alexandria and on subsequent steaming, shows that this, one of the oldest of our engineering firms, still maintains its place amongst the most progressive.

There were in the old ship eight boilers of the square box type, the length being 15 feet 7 inches, and the width 10 feet 1 inch. These had each four furnaces, making thirty-two in all, the length of the firebox being 7 feet 6 inches, and the width 3 feet 4 inches. In all there were 3,696 tubes, of an external diameter of 3 inches, and having a length of 6 feet 6 inches, so that the total heating surface was 18,860 square feet. The boilers were designed to work at a pressure of 15 pounds. The new boilers, on the other hand, are five in number, of the cylindrical type, the length being 11 feet 4¼ inches and the diameter 14 feet 3 inches. In each boiler there are three furnaces, having an inside diameter of 3 feet 4 inches, with a length of fire bar of 7 feet 6 inches, giving a grate area of 300

square feet. The total number of tubes is 1,400, and they are 3 inches in external diameter and 7 feet 3¾ inches long, so that the total heating surface is 10,170 square feet. The working steam pressure of these boilers is 160 pounds.

As is now usual in moderate power installations, there are three turbines, the high-pressure turbine being mounted on the center shaft, with a low-pressure turbine on each wing shaft; each shaft has one propeller. The astern turbines are incorporated in the same casings as the low-pressure ahead turbines. The outside diameter of the high-pressure turbine casing is 5 feet 6 inches, and of the low-pressure casing 6 feet 11 inches. The blades are fixed on the principle adopted by Messrs. Parsons.

The astern turbines, it may be mentioned, are of unusual length, which should greatly increase the stopping and maneuvering power of the ship.

The speed desired with four-fifths of the boiler power was 16 knots, and this was exceeded on a trial of six hours' duration on the Clyde. When working at full power the mean of four runs over the measured mile at Skelmorlie was 17¾ knots, the engines running at 456 revolutions, and developing 5,000 shaft horsepower.

The yacht is now 400 feet long, 42 feet beam, and of 28 feet 2 inches molded depth; on a draught of 17 feet 2 inches the displacement is 4,300 tons. The vessel now has a very much smarter appearance than before. Originally, she had two funnels, and her immense paddle-wheels detracted from the grace of outline; the new vessel has only one funnel, and looks, as she practically is, a new vessel equipped on modern lines.—"Engineering."

GERMANY.

**"Schleswig-Holstein."**—This new German battleship was launched on December 17 at Krupp's Germania shipyard, Kiel, Germany. The following are the principal dimensions: Length between perpendiculars, 121.5 millimeters (398 feet 7 inches); greatest breadth, 22.2 millimeters (72 feet 10 inches); draught, 7.62 millimeters (25 feet).

Her belt armor has a thickness of 240 millimeters ($9\frac{7}{16}$ inches) amidships, tapering down to 100 millimeters ($3\frac{15}{16}$ inches) at both ends. The armored deck extends from stem to stern, and is curved down at the sides to the lower edge of the belt armor. The ship is fitted with an armored citadel and an armored gun-deck casemate. There are also two armored conning towers, the plates of which are 300 and 140 millimeters ($11\frac{13}{16}$ and $5\frac{1}{2}$ inches) thick. The armament consists of four 28-centimeter (11-inch) guns protected by turret armor 280 millimeters (11 inches) thick; ten 17-centimeter ($6\frac{11}{16}$-inch) guns protected by the casemate armor; four 17-centimeter ($6\frac{11}{16}$-inch) guns in separate casements; twenty 8.8-centimeter ($3\frac{7}{16}$-inch) guns; four 3.7-centimeter ($1\frac{7}{16}$-inch) quick-firing guns in the fighting tops; four 8-millimeter ($\frac{5}{16}$-inch) machine guns; six under-water torpedo-launching tubes.

There are three triple-expansion main engines of 16,000 indicated horsepower, supplied with steam by twelve multitubular Schulz boilers, and designed to give the ship a speed of 18 knots. The normal coal capacity is 700 tons; this can be increased to 1,600 tons by filling the reserve coal bunkers. The double-bottom compartments will contain 200 tons of coal-tar oil, which can be used for firing the boilers.

The tonnage of the *Schleswig-Holstein* is 13,200, and four other companion ships in the same class—the *Deutschland,* the *Hanover,* the *Pommern* and the *Schlesien*—are also under construction in German yards.—"Nautical Gazette."

## ITALY.

**Destroyers and Torpedo Boats for the Italian Navy.**—In 1898 Messrs. C. and T. T. Pattison, of Naples, were commissioned by the Italian Government to build a number of 30-knot destroyers.

The design and working drawings of the hulls and machinery were supplied by Messrs. John I. Thornycroft & Co., Ltd., of Chiswick and Southampton, the boats being of a sim-

ilar type to those built by them for the British and Japanese navies.

The dimensions of this class are: Length 210 feet, beam 19 feet 6 inches, draught 7 feet 6 inches.

The engines are of the four-cylinder, triple-expansion, Thornycroft inclined, condensing type, each set having four cylinders as follows: High-pressure cylinder, 22 inches in diameter, intermediate cylinders, 29 inches in diameter, and two low-pressure cylinders, each 30 inches diameter. The stroke is 18 inches. The contract is for 6,000 I.H.P., and the designed boiler pressure is 220 pounds.

The armament consists of one 12-pounder quick-firing gun, and five 6-pounder quick-firing guns, and there are two torpedo tubes.

All the eight destroyers of this class have been launched and have fulfilled most satisfactorily the guaranteed conditions, each boat attaining a speed of at least thirty knots.

Messrs. Pattison also obtained orders for four first-class torpedo boats from designs supplied by Messrs. Thornycroft, which resembled boats recently built at Chiswick for the British Government except that twin screws were fitted instead of single screws. These boats also have gone through their trials with great success.

The mean speeds obtained on the three-hours' official trial of six of the torpedo boats were: *Pegaso,* 25.46 knots; *Perseo,* 25.72 knots; *Procione,* 26.02 knots; *Pallade,* 26.63 knots; *Cigno,* 26.40 knots; *Cassiopea,* 25.40 knots. The contract speed was 25 knots.

Subsequently to the placing of these orders the Italian Government called for tenders from Italian builders for destroyers and torpedo boats which were to be of Thornycroft type. Messrs. Ansaldo Armstrong & Co., of Genoa, and Messrs. Odero fu Alesso, of Sestri Ponente, became licensees of Messrs. Thornycroft, in Italy, and orders were placed with the former firm for four destroyers and with the latter for six torpedo boats, Messrs. Pattison also getting six additional torpedo boats.

In the design of the new destroyers Messrs. John I. Thornycroft & Co., Ltd., at the desire of the Italian Government, arranged for complete coal protection of the engines as well as the boilers of both types of boat. In the destroyers the engines are echeloned, and each engine is in a separate watertight compartment. The leading dimensions are: Length, 211 feet 6 inches; beam, 20 feet; draught, 7 feet 6 inches.

The engines are of the same type as those of the *Nembo* class already described, but the cylinders are 21 inches, 28½ inches, and two of 30 inches diameter by 18 inches stroke. There are, as in the *Nembo* class, three Thornycroft water-tube boilers. The armament consists of four 12-pounder quick-firing guns, and there are three torpedo tubes. The full complement of men is 53 in both the *Nembo* and *Bersagliere* classes.

It may here be mentioned that Messrs. Ansaldo Armstrong & Co. are also now building six stock destroyers identical in all respects with those of the *Bersagliere* class for the Italian Admiralty.

Twenty-four of the thirty Thornycroft water-tube boilers required for these ten destroyers have been or are being built by Messrs. Thornycroft at Chiswick, the remaining six being built, under license, by Messrs. Pattison at Naples.

The leading dimensions of the torpedo boats are as follows: Length, 164 feet; beam, 17 feet 4½ inches; draught, 7 feet.

The engines are of Thornycroft type and consist of two sets of vertical triple-expansion condensing engines with three cylinders 17 inches, 23½, and 36 inches in diameter, the stroke being 14 inches. They are capable of developing about 3,000 I.H.P.

There are two Thornycroft water-tube boilers in separate watertight compartments, which supply steam at 200 pounds pressure.

The armament consists of three 3-pounders and there are three torpedo tubes.

Three of these vessels have been tried and have exceeded their contract speed—the *Calliope* having attained a speed of 26.38 knots.

The destroyers and torpedo boats of Thornycroft design constructed for the Italian Navy may be seen at a glance from the following list:

| Name. | Class. | Builders. | Launched. | I.H.P. | Speed. |
|---|---|---|---|---|---|
| *Nembo* | Destroyer, | Pattison, Naples, | 1901–2, | 6,000, | 30 knots. |
| *Turbine* | Destroyer, | Pattison, Naples, | 1901–2, | 6,000, | 30 knots. |
| *Aquilone* | Destroyer, | Pattison, Naples, | 1901–2, | 6,000, | 30 knots. |
| *Borea* | Destroyer, | Pattison, Naples, | 1901–2, | 6,000, | 30 knots. |
| *Meteore* | Destroyer, | Pattison, Naples, | 1901–2, | 6,000, | 30 knots. |
| *Tuono* | Destroyer, | Pattison, Naples, | 1901–2, | 6,000, | 30 knots. |
| *Zefiro* | Destroyer, | Pattison, Naples, | 1901–2, | 6,000, | 30 knots. |
| *Espero* | Destroyer, | Pattison, Naples, | 1901–2, | 6,000, | 30 knots. |
| *Bersagliere* | Destroyer, | Ansaldo, Genoa, | Building, | 6,000, | 28½ knots. |
| *Artigliere* | Destroyer, | Ansaldo, Genoa, | Building, | 6,000, | 28½ knots. |
| *Lanciere* | Destroyer, | Ansaldo, Genoa, | Building, | 6,000, | 28½ knots. |
| *Granatiere* | Destroyer, | Ansaldo, Genoa, | Building, | 6,000, | 28½ knots. |
| *Alcione* | Torpedo boat, | Odero, Sestri, | Building, | 3,000, | 25 knots. |
| *Ardea* | Torpedo boat, | Odero, Sestri, | Building, | 3,000, | 25 knots. |
| *Albatross* | Torpedo boat, | Odero, Sestri, | Building, | 3,000, | 25 knots. |
| *Airone* | Torpedo boat, | Odero, Sestri, | Building, | 3,000, | 25 knots. |
| *Astore* | Torpedo boat, | Odero, Sestri, | Building, | 3,000, | 25 knots. |
| *Arpia* | Torpedo boat, | Odero, Sestri, | Building, | 30,00, | 25 knots. |
| *Pegaso* | Torpedo boat, | Pattison, Naples, | 1905, | 3,000, | 25 knots. |
| *Perseo* | Torpedo boat, | Pattison, Naples, | 1905, | 3,000, | 25 knots. |
| *Procione* | Torpedo boat, | Pattison, Naples, | 1905, | 3,000, | 25 knots. |
| *Pallade* | Torpedo boat, | Pattison, Naples, | 1906, | 3,000, | 25 knots. |
| *Cigno* | Torpedo boat, | Pattison, Naples, | 1906, | 3,000, | 25 knots. |
| *Cassiopea* | Torpedo boat, | Pattison, Naples, | 1906, | 3,000, | 25 knots. |
| *Calliope* | Torpedo boat, | Pattison, Naples, | Building, | 3,000, | 25 knots. |
| *Clio* | Torpedo boat, | Pattison, Naples, | Building, | 3,000, | 25 knots. |
| *Centauro* | Torpedo boat, | Pattison, Naples, | Building, | 3,000, | 25 knots. |
| *Canopo* | Torpedo boat, | Pattison, Naples, | Building, | 3,000, | 25 knots. |

—"Page's Weekly."

**Submarines for Italy.**—Three submarines have been completed for the Italian Navy—the *Delfino,* the *Glauco* and the *Squalo.* Three others are in course of construction—the *Narvalo,* the *Otario* and the *Tricheco.* The *Delfino* is rather an old craft, but she has experienced such a complete reconstruction that she may be practically considered a new boat. She has a displacement of 110 tons, and her length is 80 feet. She attained in her trials a speed of 8 knots. The *Glauco* and the *Squalo* are almost identical; their external aspect is that of a torpedo boat but they may be more properly called submersibles, while the *Delfino* is a submarine pure and simple. The *Glauco* and the *Squalo* have each a displacement of 150 tons; they are each 100 feet long. They attained in their trial a speed

of 13 knots. The *Glauco* plunged to a depth of 100 feet.—"Nautical Gazette."

**Steam Trial of the Cruiser "Coronel Bolognesi."**—The Peruvian cruiser *Coronel Bolognesi* completed at Barrow-in-Furness, on the 24th of January, her official steam trials, which were in all cases completely successful. The *Coronel Bolognesi,* with the *Almirante Grau,* have been constructed by Messrs. Vickers Sons & Maxim, Limited, for the Peruvian Navy. The *Coronel Bolognesi* differs only in having no half poop, which was adopted in the case of the *Almirante Grau,* as she is to be the flagship. The cruisers are 370 feet long, the beam being 40 feet 6 inches, with a draught of 14 feet 3 inches; the displacement is 3,200 tons. There is an armored deck throughout the whole length of the ship, which encloses the machinery compartments, magazines, steering gear, etc., while coal bunkers are arranged along the sides of the vessel to protect the vital parts of the mechanism. The conning tower has 3-inch armor. Each vessel carries a bow and a stern-chasing 6-inch gun, protected by a shield, and on each broadside there are four 14-pounder guns, which, with an installation of pom-poms, give a satisfactory offensive power for the displacement. The trials consisted of a full series of progressive-speed runs, in addition to full-power and progressive-power coal-consumption trials. During the full-speed trial the vessel made six runs over the measured mile, and attained a speed of 24.726 knots, the guaranteed rate being 24 knots. The engines, which are of the four-cylinder triple-expansion type, averaged 218.7 revolutions, the power developed being 14,384 indicated horse-power. Everything worked satisfactorily, and on the conclusion of this trial the required maneuvering tests were carried out, the vessel making circles at 14 and 18 knots. The vessel made a 24-hours' endurance test, which was divided into four successive periods of equal length, and the machinery was run at progressive powers. The results are tabulated, and alongside we give the performance at the corresponding trial of the *Almirante Grau.*

| | *Coronel Bolognesi.* | | *Almirante Grau.* | |
|---|---|---|---|---|
| | Indicated horsepower. | Coal consumption. Pounds per I.H.P. | Indicated horsepower. | Coal consumption. Pounds per I.H.P. |
| First six hours ..... | 1,078 | 2.31 | 913 | 2.27 |
| Second six hours... | 3,058 | 1.66 | 3,689 | 1.45 |
| Third six hours..... | 6,764 | 1.71 | 6,342 | 1.68 |
| Fourth six hours... | 9,485 | 1.7 | 8,817 | 1.63 |

Admiral Carvajel, the head of the Naval Commission, was present at the trials, and determined the powers at which the successive coal-consumption trials were to be run; this accounts for the variation between the *Almirante Grau* and the *Coronel Bolognesi.* The Admiral is to be congratulated on the success of his work in connection with the construction of these two vessels, as they possess a high speed and good offensive and defensive powers for their size, with a large radius of action, the distance steamed at cruising speed per ton of coal burnt being between 8 and 9 miles. It is hoped that they will form a nucleus for a new navy for Peru; they are bound to awaken interest in naval affairs among the Peruvians, may prove a satisfactory training-school, and at the same time will, when called upon, give a good account of themselves in the protection of the Peruvian coast against heavier and more costly ships not endowed with the same speed.—"Engineering."

## RUSSIA.

**The Scheme for the Reconstruction of the Russian Navy** is to build twelve battleships, fifteen cruisers, forty-six torpedo-boat destroyers, eighteen torpedo boats, ten submarines, seven gunboats, nine monitors, or coast-defense turret ships, and one mining ship. The building of these 118 vessels is to be spread over a term of nine years. The scheme has received the sanction of the Emperor, and as its details have been communicated to the Austrian press, the following account may be relied upon as correctly summarizing them:

The scheme provides for three fleets—the Baltic, the Black

Sea and the Far Eastern; whilst one stationary gunboat is told off to the Persian Gulf. For the Baltic fleet, headquarters Cronstadt, there will be built nine turret battleships, each of from 16,000 to 17,000 tons displacement, with 4 heavy (presumably 12-inch), 14 medium (probably 7¾ to 9-inch), and 56 quick-firing guns each. These ships are to be armored with nickel-steel plates 9 inches thick, and to have a speed of 18.5 knots. It will strike experts that for battleships of the future these vessels are defective, in that they will be inferior in heavy guns to any foreign ships that they might meet, except those already constructed and almost out of date. They will also be of less displacement. Four first-class cruisers of 12,000 displacement with a complete armor belt, and 5¼ inches protection to the central battery, will not carry any 12-inch guns, but are designed to accommodate 40 quick-firing guns each. There will be eighteen deep-sea torpedo boats of 250 to 300 tons each, a mining ship like the *Yenesei,* blown up near Port Arthur, and ten submarines. This concludes the Baltic fleet program.

In the Black Sea fleet the obsolete turret ships *Sinope, Ekaterina II* and *Tchesma* are to be replaced by three armored turret ships of 12,500 tons displacement, each with 4 12-inch guns, 4 7¾-inch and 12 6-inch, besides 32 small-bore quick-firing guns. These ships will carry 9-inch armor and will steam 16 knots an hour. This style of ship is not good enough for twentieth century requirements, though powerful in its somewhat antiquated way. Seven first-class cruisers are to be built for the Black Sea fleet, each of 12,750 tons, armament not yet specified; four second-class cruisers of the *Otchakoff* type, of 6,700 tons displacement, and a speed of 22 to 24 knots. These should be very useful craft. Twenty-eight torpedo boats of the *Svonki* (350 tons, 26 knots speed) type complete the list for the Black Sea. This fleet will, therefore, be in the next, as in the last, decennial period altogether behind the times as to material, which is constructed to meet past or, at most, present requirements only.

For the Far East are to be built six coast gunboats of 800 to 1,000 tons each, armed with 1 heavy, 2 medium, and 12

light guns, and a 14-knot speed; also nine shallow-draught gunboats of 250 tons each for the Amur and Sungari rivers. The total cost of this building scheme is to be 380,000,000 roubles or £38,000,000, divided into nine annual instalments, which will be added to the normal annual expenditure of 117,000,000 roubles (£11,700,000). Thus, the total annual naval budget for the next nine years will be 159,200,000 roubles (£15,920,000), which will include cost of equipment, arsenal and dock construction, etc., etc. Considering the great losses suffered by the Russian Navy during the war with Japan, this cannot be considered an excessive amount to be spent on reforming it, which is practically what has to be done. It is evident that the Russian Admiralty is not prepared as yet to lay down the ships which, according to our ideas, are now necessary—that is, battleships of nearly 20,000 tons displacement, and an armament of more than 4 12-inch guns. Of course, the future will decide who is right; we are, ourselves, on the side of the heavily-armed ship of considerable speed and coal radius, able to meet anything floating on the ocean.—"The Broad Arrow."

JAPAN.

**Launch of the "Satsuma."**—One year and one month after the peace of Portsmouth, which was brought about by the noble efforts of President Roosevelt, the launch of the largest battleship afloat took place in the presence of H. M. the Emperor, the Crown Prince, many princes and princesses, and a huge number of all classes of people, at the Yokosuka navy yard, which is but five miles from Uraga, where the monument to Commodore Perry stands.

The battleship *Satsuma,* the construction of which began in the midst of the Russo-Japanese war, is 482 feet in length, 83 feet 6 inches in beam, of 19,200 tons displacement and 18,000 horsepower. Her armament is not yet officially declared, and will be kept secret until completion. But the authorities, it is said, at first intended to provide four 12-inch guns, twelve 10-inch guns, twelve 4.7-inch guns, and five torpedo tubes. Thus it will be seen that Japan has not dispensed with intermediate

armament, as is the case with the *Dreadnought*. Incessant progress in naval matters, however, calls for some new alterations and improvements to be introduced to the armament; and the *Satsuma* will, it is believed, be finally found to be more powerfully equipped than was originally intended. Her armor belt of Krupp steel ranges from 5 to 9 (or 9½) inches, and her intended speed is 19 knots. The ram bow has been dispensed with in her, as in the two armored cruisers, *Tsukuba* and *Ikoma*, just built respectively at Kure and Yokosuka. She has a very handsome semi-fiddle bow. Over a year ago, Admiral Sir Cyprian Bridge said it would be interesting to see how long the ram bow would be a feature of warship design. So far as the Japanese are concerned, the day of the ram has passed away, and will not be revived in our future warships unless some development, as yet undiscovered, is made hereafter in naval warfare. When the *Satsuma* is fully equipped she will also be without the fighting tops so common in modern warships. Compared with our latest battleship, *Kashima*, she has a larger displacement by 2,600 tons, and in armament has eight more 10-inch guns. Not only is the *Satsuma* much superior to the *Kashima* in her exterior design, but the difference in her interior design is incomparably greater, owing to the fact that in the construction of the *Satsuma* every available experience obtained from the late war has been turned to account. The new battleship has a larger displacement than the *Dreadnought* by 1,300 tons, though she is inferior in point of speed; and there is a question as to the comparative strength of the two battleships' armaments. The *Satsuma* has four 12-inch and twelve 10-inch guns against the *Dreadnought's* ten 12-inch, so that in fire the latter opposes six 12-inch to the former ship's twelve 10-inch. The allied nations are to be congratulated upon their possession of the two most powerful battleships in the world. In the construction of warships, the most valuable of all experiences are undoubtedly those derived from the tests of actual engagements. A battleship, designed by the experts of a country which has had various experiences of modern naval warfare,

cannot fail to have many characteristics peculiar to itself; though the public are yet in the dark as to the details of those characteristics.

On November 15, when the launch had been arranged to take place, His Majesty entered the imperial stand at about 2 P. M., which faced the stem of the ship. Preparations for the launch were soon commenced. The shores supporting both sides of the hull, the wedges, etc., were removed in accordance with signal orders Nos. 1 to 14. The Minister of the Navy, Vice-Admiral Saito, then proceeded before the throne and read the following document: "On the 15th day of May in the 38th year of Meiji (1905) the construction of the battleship numbered B was commenced, and the hull having now been completed, His Majesty is pleased to name her *Satsuma*." The Minister handed the document to Vice-Admiral Kamimura, commander of the Yokosuka naval station, and the latter immediately instructed the superintendent of the arsenal, Vice-Admiral Ito, to launch the ship. As soon as the cord was cut by Vice-Admiral Ito, the hull began sliding. As the *Satsuma* was smoothly going down toward the water, a ball hanging from her bow was automatically broken, scattering pieces of colored paper, cloth, flowers, etc., from among which several pigeons flew away. The thunderous *Banzai* and applause continued for a time. The ship was entirely afloat at 2:25 P. M. It may be added that the *Satsuma* has been built entirely by Japanese experts, and there is no truth whatever in the reports circulated in Europe as to a number of foreign engineers having been employed.

SAITO TSUNETARO,
*The Imperial Fisheries Institute, Etchujima, Tokio.*

—"Scientific American."

# OBITUARY.

## BENJAMIN HOWARD WARREN.

By a Member.

It is probable that the general public would hardly count the Naval Academy as a training school for business men, although an examination of the Graduates' Register would show a not insignificant percentage of Annapolis men who have made a fine record in business life, and among these Mr. Warren occupied a notable place. His active naval career was short, lasting only from 1871 to 1878, but he was one of the most loyal sons of Annapolis and his interest in naval matters was very sincere all through his life.

He was a member of the first class of Cadet-Engineers, which entered in 1871, but did not graduate until 1874 on account of enforced absence due to illness. After a short sea service, he was retired in 1878 on account of partial deafness. This covers his active naval life except for a short time in 1898, during the Spanish War, when he was chief steel inspector in the Pittsburg district, the Government getting his services for less than a tenth of his salary in civil life.

Mr. Warren's whole life was spent as an engineer or an executive in engineering works. At first he was with the Hancock Inspirator Co. in various capacities, as mechanical engineer, European representative, and general manager. Then for some six years he was manager of the crane department of the Yale & Towne Mfg. Co., severing his connection when that department was sold to the Brown Hoisting Co., of Cleveland. For a short time he was with the Pratt and Whitney Co., and then joined the Westinghouse Electric Co.

It was during his service with this company that Mr. Warren made his great reputation as an executive. He began as assistant general manager in charge of manufacturing, and

displayed such remarkable talents as an organizer that Geo. Westinghouse, the head of the great company, made him a vice-president in charge of manufacturing and commercial operations. The growth of the company during his administration was phenomenal, and a large share of the credit for its success has always been given to Mr. Warren. He was a rigid disciplinarian, stern and sometimes severe, but scrupulously fair and just to everybody. At the end of 1901 he resigned his position and devoted himself to the care of a moderate fortune which he had accumulated, and to the enjoyment of a beautiful estate he had purchased near Charlottesville, Va. In 1904 he was invited to become the President of the Allis-Chalmers Co., another great manufacturing concern, a position which he filled until September, 1905, when he resigned on account of impaired health. In the early part of this year he became a partner in the firm of Kafer, Mattice & Warren, consulting engineers. His death on October 20th from apoplexy, in his 57th year, was totally unexpected.

Mr. Warren was a man of warm affections, although not demonstrative, and sincerely devoted to any cause in which he was interested. He was very active in the New England Association of Naval Engineers, frequently making the journey of seven hundred miles from Pittsburg to attend the annual dinner. For a time he was the owner of "The Engineer" of New York, and opened its columns freely to the discussion of naval matters. He was also the publisher of Bennett's History of the Steam Navy of the United States. By inheritance from his father, who was an officer of the Army in the Civil War (killed at the battle of the Wilderness), he was a companion of the Loyal Legion. He had been a vice-president of the Society of Mechanical Engineers, and was also a member of the Society of Naval Architects and Marine Engineers. He was an early member of the Engineers Club of New York and always very active in its affairs. He leaves a widow, two daughters and a son, and his was the first death in a family circle of rare charm and one which it was a privilege to enter as a friend. He had a very wide acquaintance in

engineering and manufacturing circles and counted among his personal friends most of the leaders in the profession.

It was a remarkable fact that his death is the first among the engineer graduates of 1874.

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## CHARLES HARDING LORING.

By W. M. McFarland, Member.

On February 5th there passed away after a long and distinguished life a man who had always upheld the highest traditions of the Service and who, under all circumstances, has been one of its ornaments, Charles Harding Loring, Chief Engineer, with the rank of Rear Admiral. All the highest honors of the engineering profession had been conferred upon him, both on the scientific and social sides, thus bearing marked tribute to his eminence as an engineer and to his sterling worth and personal charm as a man.

He was born in Boston December 26, 1828, and received his education in the public schools of that city. As his educational period was before the day of technical schools, he followed the usual course of preparation for mechanical engineering and served a regular apprenticeship in the machine shop. At its close, in 1851, he entered the Navy as a third assistant engineer, attaining, by competitive examination, the highest place in a class of fourteen.

His entrance was just too late to give him an opportunity for participation in the Mexican War, and by the time the Civil War broke out he had passed through all the junior grades and had become a chief engineer. During his service in junior grades he had been laying the foundation for his more important work when an older man and in higher positions, a portion of his shore duty having been as assistant to the Engineer-in-Chief of the Navy, Mr. Samuel Archbold, in which capacity he had charge of the experimental work and tests of engineering devices coming before that office. It is interesting to note that while engaged in this duty he made a test of the first injector which came to this country.

During the Civil War he was in active service the whole time, and during the first eighteen months was fleet engineer of the North Atlantic Station, being attached to the fine old steamer *Minnesota*. He was on board this ship during the attacks of the *Merrimac* on the Northern fleet in Hampton Roads on the eighth and ninth of March, 1862, when the *Cumberland* was sunk and the *Congress* burned, and when the *Minnesota* also was attacked.

A little later he was detached from sea duty and sent to Cincinnati to supervise the construction of three river and harbor monitors and also of some light-draught sea monitors building there. Subsequently he was made general inspector of all the iron-clad steamers building west of the Alleghanies, having in charge at one time eleven monitors building at Pittsburg, Cincinnati and St. Louis.

During the Civil War a number of excellent engines had been accumulated for hulls which were in process of construction, but with the close of the war all work was stopped, and after a time a board was appointed to recommend the best disposition of these engines which were stored in the various navy yards. It was about this time that the compound engine was coming into general use, and the same board was directed to make a study of the compound engine with a view to its introduction in naval vessels. Of this board Admiral Loring was senior member, and associated with him was the late Chief Engineer Charles H. Baker.

After a very exhaustive study of the subject, they recommended the introduction of compound engines and the abandonment of the simple form, and the conversion of a number of the engines which were on hand into compound engines. Four sets of these simple engines were so converted and were fitted to the *Vandalia, Marion, Quinnebaug* and *Swatara*. The tests of these engines were very satisfactory and showed a coal economy for short runs of not much over two pounds of coal per horsepower hour.

This study of the compound engine made it natural that Admiral Loring should be selected as the representative of the

Navy Department when, in 1874, he and the late Dr. Charles E. Emery made an elaborate series of trials of the engines of the revenue cutters *Rush, Dexter, Dallas* and *Gallatin,* to determine by actual test the relative economies of compound and simple engines, designed for the same work in similar hulls, and also to secure reliable and authoritative data with respect to the economy of steam jacketing. These tests were the first of the kind conducted under circumstances of entire reliability, with the result that the report of the trials was republished all over the world and is still quoted in all the text books on steam engineering.

Admiral Loring's next tour of sea duty was as a fleet engineer of the Asiatic Station on the U. S. S. *Tennessee,* where he had as his chief assistant, George W. Melville, who later became his successor as chief of the Bureau of Steam Engineering. There was nothing specially eventful in this cruise, and at its end, in 1880, he was assigned as the head of the steam engineering department of the New York Navy Yard.

This was the period of greatest inactivity in the history of the Navy, and there was little to do, even for a very active man, except routine work. During this tour, however, Admiral Loring was senior member of a board that made a test of the machinery of the *Anthracite,* a little yacht with a triple-expansion engine working with 600 pounds pressure. The experiments were valuable as showing that, with the form of apparatus on board the *Anthracite,* there was no such gain in economy as to warrant the tremendous pressure carried, while it involved numerous practical difficulties.

In 1881 he was a member of what is known as the "First Naval Advisory Board," appointed by Secretary Hunt to formulate a shipbuilding program for the Navy which he might submit to Congress. The personnel of this advisory board was distinguished in all its branches, and the work they did made possible our splendid fleet of today, as they definitely decided to abandon wooden hulls for those of iron and steel, and for general progress in every respect. In 1882 he was a member of another important board known as the "Navy Yard

Board," of which Admiral Luce was senior member. The duty of this board was to visit all the navy yards of the country for the purpose of determining which of them might with advantage and economy be closed. It was a delicate task, but the report, when finally approved, gave general satisfaction, and its recommendations were carried out.

On the retirement of Engineer-in-Chief Shock only two successors were thought of, one of whom was Admiral Loring, and his merit and thorough qualification for the position were so well recognized that the appointment came to him entirely unsought. This was in 1884, during the administration of President Arthur. Secretary Chandler was presiding over the Navy Department at this time, and it was under his supervision that the four vessels commonly known as the Roach cruisers, the *Atlanta, Boston, Chicago* and *Dolphin,* were built.

Part of the scheme of building the new navy was the organization of what was known as an "Advisory Board," composed of two civilians and a number of naval officers. Owing to this régimé the bureaus were not given the same free hand that has obtained since the advisory board was discontinued, although they did valuable work in the details of designs. Forced draft was used on these new vessels, after having been tried on two others—the *Alliance* and *Swatara*—under Admiral Loring's direction.

In 1885, with the advent of a new administration, there was a general spirit of unrest about the Navy Department from what seemed to be a prevailing belief that whatever was, was wrong. The air was filled with rumors of intended changes, among them one which promised to cause a violation of the contract labor law, as it was actually seriously under consideration to import a British engineer and put him in charge of the design of machinery. From this intent and other indications it became evident to Admiral Loring that he did not enjoy the Secretary's confidence, and he tendered his resignation.

After leaving the Bureau of Steam Engineering he was

made senior member of the Experimental Board of Naval Officers at the New York Navy Yard, which board, under his direction, conducted many exceedingly valuable experiments. Among the most important were the competitive tests of water-tube boilers to determine the type that should be used on the coast-defence vessel *Monterey,* and it may be well here to call attention to the fact that this was the first case on record where a boiler had ever been run for twenty-four hours when burning more than fifty pounds of coal per square foot of grate.

Another very important series of experiments conducted by Admiral Loring were those on the boilers of the torpedo boat *Cushing,* to determine the economy of evaporation with different air pressures and rates of combustion. These experiments have proven of the greatest interest, and form a very valuable collection of engineering data. A number of clever devices had to be schemed out to carry on these tests, and the whole success was a great credit to Admiral Loring and the board.

Having reached the age limit in December, 1890, he was placed on the retired list; but having always been a man of very vigorous physique, he did not give up active employment, and was for a time consulting engineer to the United States and Brazil Mail Steamship Company. During the late war with Spain he was recalled to active duty and assigned as inspector of engineering work in New York City.

This record shows the active naval work of Admiral Loring, but to those who knew him well, this side of his character was less important than the social one. Although a man of great dignity, he was what is now called "a good mixer," being most companionable and a delightful associate. He wrote well and was a good speaker, but he was perhaps at his best in a party of moderate size where his keen sense of humor, his genial personality and his remarkable skill as a raconteur made him a most enjoyable associate.

He was for two years president of the Engineers' Club of New York, which is a sure test of popularity and wide ac-

quaintance in the engineering world. He was also president of the American Society of Mechanical Engineers, the highest honor which his branch of the profession could confer. He was a vice-president of the Society of Naval Architects and Marine Engineers from its formation until his death, and, as long as his health permitted, was very active in its council and general meetings. He was a member of our own Society from the beginning. He had also been very active in the Army and Navy Club of New Yŏrk, filling various offices and acting as its secretary for several years.

Time had dealt gently with his appearance, and although in his seventy-ninth year when he died, he did not look much over sixty. Until the last few years he had been very robust, but he had been ailing for some time and finally succumbed to an attack of paralysis.

Admiral Loring's career covered almost the whole period of progress in marine engineering from the side-wheel engine and box boilers down to the triple-expansion engine and steam turbine, forced draft and the water-tube boiler. In nearly all of this progress he played an important part, and he could justly feel that he had not only done his duty but had been a factor in the continued advancement of the profession and the service he loved so well.

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## ALFRED BRUCE CANAGA.

By a Member.

It is not often that the death of an officer causes such general and sincere sorrow as that of Commander Canaga, who was affectionately called by his intimate friends, "Pop." His character and disposition were so admirable and uniform that no one could be associated with him without becoming a warm friend. The well-known lines about Abou Ben Adhem tell us that he was given a high place in the good book because he loved his fellow men. Surely dear old "Pop" will rank equally high. His kindness and consideration for others and his help-

fulness to all his associates make his record one to be admired but almost impossible to equal.

Commander Canaga was an honor man in the second class of Cadet Engineers, graduating in 1874. It is rather remarkable to note that the ranks of the ten graduates of this class had not been broken until the death of Mr. Warren in October, followed so soon by that of Commander Canaga on December 24, 1906.

Of his active naval life, about half (some sixteen years) was spent at sea, covering almost every part of the globe. It happened, too, as a common thing with him for his cruises to extend beyond the usual three years. His shore duty was all of a very important nature and commensurate with his high order of ability. He was twice on duty at the Bureau of Steam Engineering as the chief designer, in charge of the drawing room, during which time many of the designs for our most important vessels of the new navy were worked out. He also did some important educational work, as an instructor at the Naval Academy and as a professor at Cornell University. He had been Chief Engineer of the Cavite Dock Yard, and was on duty as Chief Engineer of the Boston Navy Yard at the time of his death.

Such is a brief statement of a very busy life, full of work, always well done. A man of high character and unblemished reputation, he leaves a record which is a source of just pride to his family and of affectionate remembrance by his host of friends. He had just completed his 56th year, having been born November 2, 1850.

He leaves a widow, a daughter, and a son who is an Ensign in the Navy.

# ASSOCIATION NOTES.

The regular annual meeting of the Society was held at the Navy Department, Washington, D. C., on December 27, 1906, for the purpose of electing officers for 1907.

A count of the votes received resulted in the election of the following officers:

*President*, Commander B. C. Bryan, U. S. Navy.

*Secretary-Treasurer*, Commander Theo. C. Fenton, U. S. Navy (retired).

*Members of the Council*, Captain A. F. Dixon, U. S. Navy; Commander R. S. Griffin, U. S. Navy; Commander H. P. Norton, U. S. Navy.

The following is the statement of the Secretary-Treasurer for the year ending Dec. 31, 1906:

| | | |
|---|---|---|
| *Received, 1906:* | | |
| Dues and subscriptions | $3,911.35 | |
| Advertisements | 1,834.87 | |
| Sales | 544.73 | |
| Interest | 184.73 | |
| Total receipts | | 6,475.68 |
| Balance received Jan. 1, 1906 | | 5,746.63 |
| | | $12,222.31 |
| *Expended:* | | |
| Printing and stationery | $4,319.29 | |
| Engraving | 685.05 | |
| Salary Secretary-Treasurer | 900.00 | |
| Purchase of JOURNALS | 12.50 | |
| Articles paid for | 100.00 | |
| Postage, expressage, incidentals | 72.00 | |
| Purchase of five (5) $1,000 bonds, Washington Railway and Electric Co | 4,400.00 | |
| Total expended | | $10,488.84 |
| Cash balance | | $1,733.47 |

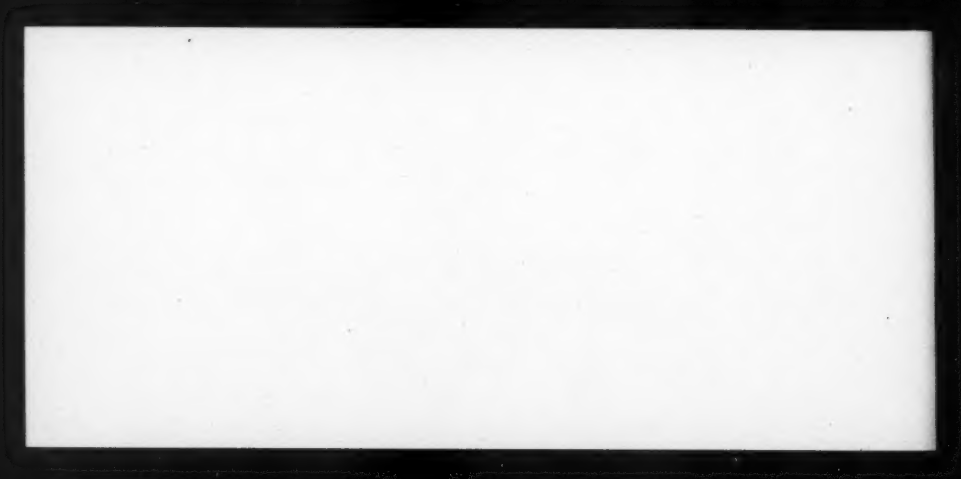
| | |
|---|---|
| Available assets of the Society, January 1, 1907, cash balance... | 1,733.47 |
| Five (5) $1,000 bonds (cost)..... | 4,400.00 |
| Total..... | $6,133.47 |
| Total value, Jan. 1, 1906, cash..... | 5,746.63 |
| Net gain for year 1906..... | $386.84 |

This statement was audited by a committee of the Council and found to be correct.

THEO. C. FENTON, *Commander, U. S. N., Retired,*
*Secretary-Treasurer.*

B. C. BRYAN, *Commander, U. S. N.,*
*President.*

## ERRATA.

Volume XIX, No. 1, page 192:

Temperature of smoke stack: read 517 for 450.
Revolutions, blower engines: read 369.7 for 138.
Revolutions, dynamos: omit 118.